

From the DEPARTMENT OF CLINICAL SCIENCE AND
EDUCATION, SÖDERSJUKHUSET
Karolinska Institutet, Stockholm, Sweden

PREHOSPITAL CARE OF SEVERELY INJURED TRAUMA PATIENTS: STUDIES ON MANAGEMENT, ASSESSMENT, AND OUTCOME

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**Karolinska
Institutet**

Stockholm 2016

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Published by Karolinska Institutet.

Printed by Eprint AB 2016

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ISBN 978-91-7676-481-7

Prehospital Care of Severely Injured Trauma Patients: Studies on Management, Assessment and Outcome

THESIS FOR DOCTORAL DEGREE (Ph.D.)

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“För att de utsatta skall vara de utvalda”

To Hasse, Noah, Joel, and Adam

ABSTRACT

Trauma is a public health issue. According to statistics from the Swedish National Board of Health and Welfare, circumstances related to injury are the most common cause of death in the age group 15–44 years for both genders. Prehospital care is the first link in the chain of life support. Trauma systems and regionalized trauma care have been shown to improve outcome in severely injured trauma patients, but less is known about whether gender influences the prehospital trauma care. Management in the prehospital phase of traumatic brain injury (TBI) is focused on limiting the effects of secondary insults, such as hypoxia and hypotension, and advanced prehospital airway management might potentially improve the outcome. The overall aim of this thesis was to evaluate the prehospital assessment, management and outcome in severely injured trauma patients within a regional trauma system.

Paper I. A retrospective observational study based on local trauma registries and hospital and ambulance records in Stockholm County. 693 primarily admitted trauma patients were included for the years 2006 and 2008. For the years 2006, 2008, and 2013, there were 114 secondarily transported trauma patients. The number of primary patient transports to the trauma center increased during these years by 20.2%, ($p < 0.001$). Primarily transported patients had a significantly higher Injury Severity Score (ISS) in 2008 than in 2006, and the number of patients transported secondarily to the trauma center in 2006 was higher compared to 2008 and 2013 ($p < 0.001$).

Paper II. A retrospective observational study based on local trauma registries and hospital and ambulance records in Stockholm County. A total of 383 trauma patients (279 males and 104 females) >15 years of age with an ISS of >15 transported to emergency care hospitals in the Stockholm area were included. Male patients had a 2.75 higher odds ratio (95% CI, 1.2–6.2) for receiving the highest prehospital priority compared to females on controlling for injury mechanism and vital signs on scene.

Paper III. A retrospective observational study based on 2750 prehospital medical records of suspected TBI patients. 25.2 % of the patients were assessed according to all four core-elements in the guidelines and 78.6% of the patients underwent at least one intervention by the PECNs. Male patients were to a higher extent assessed according to guidelines and were given higher transport priority while females were more often assessed for vital parameters and received significantly more analgesics.

Paper IV. A retrospective observational study based on 459 TBI patients ≥ 15 years admitted to the neurosurgical unit in Stockholm between the years 2008 and 2014. High energy trauma, prehospital hypotension, pupil unresponsiveness, mode of transportation and distance to the hospital were independently related to an increased rate of pre-hospital intubation (model explained $p < 0.001$, pseudo- R^2 0.482). Pre-hospital intubation did not correlate to outcome of the unconscious patients ($p = 0.296$), or add independent information to the model of significant parameters in multivariate analysis vs. GOS ($p = 0.154$). Transports >10 km had an intubation frequency of about 50%.

With the introduction of a prehospital trauma transport directive, an increase in patients transported to the regional trauma center and a decrease in secondary transfers were detected, but a considerable number of severely injured patients were still transported to local hospitals. The results also indicated that prehospital prioritization among the severely injured and the assessment and management of parameters related to head trauma differed between genders. Pre-hospital intubation could not be related to outcome. Large multicenter prospective studies with structured protocols are of importance in order to determine potentially beneficial effects of prehospital advanced airway management.

LIST OF SCIENTIFIC PAPERS

- I. Effect of an organizational change in a prehospital trauma care protocol and trauma transport directive in a large urban city: a before and after study.
Rubenson Wahlin R, Ponzer S, Skrifvars M, Lossius HM, Castrén M.
Scand J Trauma Resusc Emerg Med. 2016 Mar 9;24:26.
- II. Do male and female trauma patients receive the same prehospital care?: an observational follow-up study.
Rubenson Wahlin R, Ponzer S, Lövbrand H, Skrifvars M, Lossius HM, Castrén M.
BMC Emerg Med. 2016 Jan 19;16:6
- III. Patients with head trauma: a study on initial prehospital assessment and care.
Rubenson Wahlin R, Lindström V, Ponzer S, Vicente V
Submitted
- IV. Prehospital advanced airway management of patients with traumatic brain injury; relations to outcome in a Swedish trauma cohort
Rebecka Rubenson Wahlin, David Nelson, Bo-Michael Bellander, Mikael Svensson and Eric Peter Thelin.
Manuscript

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LIST OF ABBREVIATIONS

AAAM	Association for the Advancement of Automotive Medicine
ARDS	Acute Respiratory Distress Syndrome
ATLS	Advanced Trauma Life Support
ACS	American College of Surgeons
AIS	Abbreviated Injury Scale
CBF	Cerebral Blood Flow
CI	Confidence interval
CPR	Cardiopulmonary resuscitation
EMS	Emergency Medical Services
ePCR	Electronic Patient Care Record
EMT	Emergency Medical Technicians
GCS	Glasgow Coma Scale
GOS	Glasgow Outcome Score
HEMS	Helicopter Emergency Medical Services
ICP	Intracerebral Pressure
ICU	Intensive Care Unit
IQR	Interquartile Range
ISS	Injury Severity Score
KSS	Karolinska University Hospital in Solna
QUITC/KVITTRA	Quality in trauma care
LOS	Length of stay (days)
MAP	Mean Arterial Pressure
MICU	Mobile Intensive Care Unit
NACA	National Advisory Committee for Aeronautics
OR	Odds Ratio
PECN	Prehospital Emergency Care Nurse
PHETI	Prehospital endotracheal intubation
PHTLS	Prehospital Trauma Life Support
RN	Registered Nurse
ROSC	Return of spontaneous circulation

RR	Respiratory rate
RTI	Road Traffic Accidents
RTS	Revised Trauma Score
SBP	Systolic blood pressure
SCC	Stockholm County Council
SFAI	Swedish Society for Anesthesia and Intensive Care
TRISS	Trauma and Injury Severity Score
WHO	World Health Organization

1 INTRODUCTION

1.1 EPIDEMIOLOGY OF TRAUMA AND TRAUMATIC BRAIN INJURY

The word trauma has its origin in ancient Greek, τραῦμα, which literally means wound. Trauma can have various meanings depending on the context in which it is used. The definition of the word trauma used in this thesis is the definition used by the Center for Disease Control and Prevention (CDC)/The National Institute for Occupational Safety and Health (NIOSH) [1]. The terms trauma and injury are used interchangeably in this thesis: *“An injury or a wound to a living body caused by the application of external force or violence.”*

Trauma is a public health problem. The World Health Organization (WHO) has estimated that more than 5 million people die every year from injuries, which is 9% of all deaths [2]. Or, in other words, about one out of ten deaths is caused by an injury. Since 1990, a 24% rise in deaths related to trauma has been reported [3] and is now almost 1.7 times the number of people who die from HIV/AIDS, malaria, and tuberculosis together. Among those aged 15–29, the leading cause of death worldwide is road traffic injuries and, in the elderly population, falls constitute the most frequent cause of injury related to death [2, 3].

Globally, there are some types of injuries and violence which affect females to a much greater extent than males, e.g., physical and/or sexual violence among girls at some point in their childhood is estimated to average 20% vs. 10% in boys, but this varies widely of course across global regions [4].

Regarding the incidence of major trauma (defined as Injury Severity Score, ISS >15) in Scandinavia, the range is between 30 and 52/100,000 inhabitants per year. As for the rest of Europe, the dominant trauma mechanism is blunt trauma and just about 9–12% of all traumas are due to penetrating injuries, which results in an incidence of 2–3/100,000 per year [5-9] [10-12].

The economic aspect of the burden of injury is also a major issue even though there are differences between high-income and low-income countries. About 2% of the gross domestic product in high-income nations is ascribable to road traffic deaths and injuries, compared to as much as 5% in some low- and middle-income countries [2]. In Sweden, the cost for injuries in 2005 was SEK 59 billion and 75% were due to road traffic accidents and falls [5].

Statistics from the Swedish National Board of Health and Welfare show that, in 2014, 3210 persons in Sweden, or 4% of the population, died of causes related to injuries (ICD-10 chapter XX, “Causes of Morbidity and Mortality”, and the ICD-10 codes V01–Y98) and this was the most common cause of death in the age group 15–44 years among both males and females [13].

Traumatic brain injury (TBI) is also of major concern for the public health. Every year, approximately 10 million people are affected globally [14]. TBI has been reported to be the leading cause of death in persons under the age of 45 [15, 16] and is a major cause of permanent disability [15, 17], resulting in substantial costs from a socioeconomic point of view [17] [18]. TBI has been regarded as mainly afflicting young adults, but the trend appears to be shifting, especially in high-income countries, towards the elderly population [19] and thus negatively affects the overall outcome for TBI. Among the over 2 million emergency department (ED) visits annually in the US, TBI is the primary or secondary diagnosis, i.e., 3.2 million people, or 1% of the US population, suffer long-term disability from a TBI [20]. In Europe, the mean incidence of TBI (hospitalized and fatal cases) is 235 per 100,000 annually [16]. If the post-TBI disability prevalence in Europe would be estimated to be the same as in the US [20], more than 6 million people in Europe would suffer from long-term TBI disability [14].

In Sweden, TBI is most common in the age groups under 25 or over 65 and affects more males than females, approximately two out of three patients being males [21]. Falls constitute the majority of TBI cases (55%) and occur predominantly among the elderly, followed by road traffic incidents (RTIs) (30%) in the younger population [22, 23]. The incidence rate for TBI is 260/100,000/year and the mortality rate is 9.5/100,000/year in Sweden [16, 21, 24]. In other words, even with a slightly higher incidence of TBI in Sweden than in Europe overall, the mortality is lower.

It is, however, important to bear in mind that injury prevention is made possible by well-established prevention strategies, particularly in high-income countries. For example, in Sweden, the rate of child injuries has decreased over the past few decades by about 75% [2].

1.2 PREHOSPITAL TRAUMA CARE

The main goals for trauma care are survival of the injured patient and to reduce the morbidity and to improve quality of life post injury. There are important components in the physiology of trauma that affect the outcome the primary injury (the actual accident), the

secondary injury (interventions, treatment, and events and complications after the primary injury) and the individual biological response (the comorbidity of the individual) to the trauma [25, 26].

Prehospital trauma care systems differ throughout the world, but most countries have implemented the principals of Basic Life Support (BLS) and Advanced Life Support (ALS). The providers can be paramedics, nurses, and/or physicians and the type of transportation ground or airborne. There is no evidence related to patient outcome that favors either of the prehospital systems [26-30].

1.2.1 Prehospital trauma care and ABCDE principles

During the past decade, most givers of prehospital care in Sweden have incorporated the prehospital trauma life support (PHTLS®) concept in their training for prehospital providers [26]. The course has been available in Sweden since 1998 and the Swedish Society for Anesthesia and Intensive Care (SFAI) has been responsible for the medical content of the course [31]. PHTLS® is an international educational program for prehospital emergency trauma care focused on the ABCDE principles and is evidence-based [26]. A rapid and accurate field assessment and transport to an appropriate trauma center is considered to decrease mortality and morbidity among patients with traumatic injuries [26]. This approach to prehospital trauma care have also been incorporated in the prehospital guidelines in Stockholm County [32].

The goals of prehospital trauma care are an efficient and accurate assessment, early and prompt recognition of hypoxemia and shock, proper intervention at the right place and time, and transport to the right facility at the right time [25, 26]. The prehospital assessment consists of a primary and a secondary survey. The primary survey is performed in accordance with the ABCDE principles in order to rapidly detect any failure of vital functions. The secondary survey is a full-body assessment to detect anatomical injuries [25, 26]. According to the guidelines of the Stockholm County Council (SCC), a critical trauma patient should be transported from the field within 10 minutes and treatment should be initiated and maintained during transport [32].

1.2.2 Airway (with cervical stabilization) and breathing

To assess and properly manage a compromised airway and ensure adequate pulmonary ventilation is the first and most important prehospital intervention. Ensuring a proper airway and support ventilation, so as to allow the trauma patient to oxygenate sensitive ischemic organs, will minimize the overall morbidity and mortality [33-35]. The assessment

should include auscultation, measuring the SaO₂ and the respiratory rate. Airway management also includes stabilization of a possibly damaged spine for to protect against secondary spinal cord injuries [36]. The patients with a Glasgow Outcome Score (GCS) of 3–8 should be considered concerning the risk for potential airway problems. There are several techniques available when managing the airway. Manual methods include the jaw thrust and the chin lift to allow the tongue to unblock the pharynx [26]. Methods considered to be simple are the oropharyngeal and nasopharyngeal airways and the complex methods are the supraglottic airway, endotracheal intubation (ETI) (with or without pharmacological agents), and the percutaneous and surgical airways [26, 36]. To help support ventilation, the bag mask is used most frequently, together with simple or complex airway devices. When used with simple devices, the bag mask does not constitute a secure airway and does constitute a risk for aspiration of gastric contents. However, sometimes it is the best choice of airway management when ETI is not available [37].

ETI has been regarded as the golden standard because it prevents aspiration of blood and gastric contents [36], but the evidence is inconclusive as to whether it actually improves the outcome in the prehospital setting [33, 38, 39]. Complications of ETI include esophageal intubation, hypoxemia/hypercarbia from numerous attempts, bradycardia, increased ICP, soft tissue/vocal cord/tooth trauma, and aspiration [26, 36, 40-44]. There are data supporting the possibility that when ETI is performed by less experienced EMS providers or is done incorrectly, it might be fatal [39]. There is still a need for more reliable data to establish whether prehospital ETI improves the outcome. An international template for reporting advanced prehospital airway management was developed in 2011 and might help to add evidence and improve data quality in studies on prehospital airway management [38]. Pneumothorax is also a condition that should be considered, and particularly tension pneumothorax, which, if left untreated, might lead to cardiac arrest [26].

1.2.3 Circulation and hemorrhage control

The majority of the preventable trauma deaths are a result of hemorrhagic shock.[45] Uncontrolled bleeding causes general hypoperfusion of tissues and leads to cellular hypoxia, lactic acidosis due to anaerobic metabolism, organ failure, and eventually death [46]. When treated in time, the hemorrhagic shock might be reversed [46]. It is therefore important that an uncontrolled bleeding is detected as soon as possible in the field in order to minimize the time from the traumatic event to definitive hemorrhage control at the trauma center [46]. The prehospital treatment of bleeding is direct hemorrhage control (by

pressure, if possible), preventing hypothermia, and initiation of fluid resuscitation [46, 47]. The prehospital assessment should also include blood pressure, pulse, and capillary refill.

The evidence concerning which fluids should be given and when resuscitation should be initiated is still inconclusive [48]. However, it is important to maintain a mean arterial pressure (MAP) to allow sufficient tissue perfusion but not to overinfuse fluids [47]. If too much volume is administered, the risk of bleeding increases since the blood-clotting factors are then diluted and an increased MAP may cause disruption of blood clots [47, 48]. In addition, high-volume administration increases the risk of acute respiratory distress syndrome (ARDS) and also the risk of compartment syndrome involving the extremities and abdomen [49]. Permissive hypotension has become the European recommendation for fluid resuscitation, which means low-volume administration of fluids targeting a systolic blood pressure of around 80–100 mmHg or maintaining a palpable radial pulse and/or an uncompromised mental status [26, 50] in patients without suspected head or spinal trauma [46]. In suspected head or spinal injury, the fluids should be administered in higher volumes to ensure sufficient intracerebral circulation. The recommended fluid is crystalloids (Ringer's Acetate) or, alternatively, hypertonic solutions (RescueFlow®) [46]. Addition of colloids (Voluven®) could be considered for hemodynamically unstable patients [46] but needs to be individualised.

1.2.4 Disability

Disability procedures include assessment of the patient's neurological status, the level of consciousness, sensory and motor responses, and pupillary light reflexes [51]. The most frequently used measuring instrument is the Glasgow Coma Scale. Patients with suspected spinal cord injuries should be immobilized to avoid or to minimize secondary injury [52] and patients with suspected traumatic brain injury should also be immobilized since a co-existing cervical fracture is quite common. The appropriate immobilization includes both a cervical collar and a spine board to ensure proper stabilization [52].

1.2.5 Exposure

The assessment includes whole body inspection to identify all signs of trauma and to measure the temperature [51]. Interventions include prevention of hypothermia by removing wet clothes, covering the patient with blankets, and infusion of warm fluids [46]. Hypothermia prevention is important (core temperature <35°C) since it is associated with increased mortality due to severe hemorrhage, hypotension, coagulopathy, and acidosis in trauma patients [46].

1.2.6 Analgesics

Historically speaking, prehospital use of analgesics in trauma patients has been restrictive due to the fear of such side effects as respiratory depression [53]. Apart from unnecessary patient suffering, less use of analgesics has been associated with unfavorable outcomes for trauma patients [54]. It has been reported that inadequate patient analgesia might be correlated with, pulmonary complications, chronic pain, increased thromboembolic events, prolonged hospital times, and even mortality [55].

There is lack of evidence for recommending one specific analgesic drug in the prehospital setting [56]. The analgesics used in Stockholm are morphine, alfentanil (Rapifen®), and ketamine (Ketalar®) [32]. Morphine is the most frequently used and predominantly administered intravenously. Alfentanil is a synthetic intravenously administered opiate with stronger analgesic effect and with higher risk for respiratory depression [57]. It has a rapid onset and short duration [57]. Ketamine is a dissociative anesthetic with analgesic effects in sub-anesthetic doses. Ketamine stimulates the cardiovascular system and dilates bronchioles, but does not depress airway reflexes and does not affect the hemodynamics as much as other anesthetics. These features make ketamine suitable for prehospital analgesia and anesthesia since it can be used in hemodynamically unstable patients. Ketamine might be administered both intravenously and intramuscularly [57], which is particularly suitable in the prehospital setting where vascular access might be challenging.

1.3 PREHOSPITAL CARE OF PATIENTS WITH TRAUMATIC BRAIN INJURY

1.3.1 Primary Injury

The primary injury is a result of external forces transferring kinetic energy to the brain at the traumatic event. The severity of the primary injury is dependent on the extent of trauma, direction, intensity, and duration irrespective of the traumatic cause [58]. Different pathologies can develop from the external forces [58], e.g., contusions, hematomas, tearing of blood vessels, and diffuse axonal injuries (DAIs) [58], and are dependent on the individual's age and gender, comorbidity, and the energy of the trauma. Nearly half of all fatal TBIs occur within the first two hours of trauma and are often due to extensive brain damage or extra-cranial bleeding [59]. The primary injury can only be avoided by preventing the traumatic event.

1.3.2 Secondary Injury

Secondary brain injury is a process following the primary brain injury, which contributes to the pathogenesis of TBI and develops over hours, days, and weeks [60, 61]. The process includes elevated intracerebral pressure (ICP), decreased cerebral blood flow (CBF), cerebral hypoxia, hemorrhage, and the neurochemical injury cascade [58, 60]. Further damage occurs from cerebral metabolic dysfunction, free-radical release, neurotransmitters, inflammatory responses, and gene activation [58]. Most therapies developed with the aim of reducing the secondary injuries show conflicting results, probably due to the heterogeneous pathology of TBI, which makes recommendations for treatment difficult.

1.3.3 Prehospital management of TBI

The aim of prehospital management of TBI is to avoid or minimize the secondary brain injury by optimizing the treatment immediately after trauma at the scene of the accident [62, 63] and this has been shown to reduce morbidity and mortality [64]. The Scandinavian guidelines for prehospital management of severe TBI were published in 2008 as an attempt to guide and standardize the prehospital care [59]. Prehospital TBI management focuses on prevention of secondary brain injury by ensuring appropriate airway management, oxygenation, and blood pressure [65]. A GCS assessment, pupil properties, and direct transport to a designated neurotrauma center are other key elements in the current guidelines [65].

1.4 TRAUMA SYSTEMS

”A trauma system combines the cooperation of prehospital, hospital, and rehabilitation facilities within a defined geographic area integrated with a regional public health system” [66] Chapter 1, p 2.

This is a definition of a trauma care system by Hofman and Pepe, and the goal can be described as:

“To provide the best possible care to traumatically injured patients, according to the severity of their injuries, in the fastest possible way. Such care will be provided by designated trauma centers with different levels of care” [66] Chapter 1, p 2.

Trauma care and trauma systems originate from the military emergency care services, where systematic management of the severely injured trauma patient was developed [26, 67, 68]. From the “flying ambulances” during the Napoleonic wars in the 19th century [68-70] up to the war in Vietnam in the 1960s and 1970s, important knowledge was gained concerning how

to triage, treat, and transport soldiers from the field, thereby resulting in increased survival rates [67, 68, 70-72].

In the 1920s, the first trauma system in Europe was established in Austria and, in the 1940s, the first trauma center was founded, the Birmingham Accident Hospital, which was in use until the middle of the 1990s [73]. In 1966, the first trauma centers were established in the USA, namely, the Cook County Hospital in Chicago, Illinois, [74] and the San Francisco General Hospital in California [68, 70, 75] . After the first centers were established, new centers were opened all over the USA during following years, thus leading to the development of the first trauma system in 1969, which was the Maryland System of Trauma Care [68].

During the 1970s in Germany, the trauma care systems were developed, including trauma centers and ambulance and helicopter services, in proximity to the Autobahn in order to enable swift transportation of patients [68, 70].

Further development of the trauma systems began in the 1960s and 1970s, simultaneously with the return of medically trained military personnel from the war in Vietnam. A publication of the National Academy of Sciences in the USA in 1966, entitled “*Accidental Death and Disability, the Neglected Disease of Modern Society*”, [76] highlighted the benefits of organized trauma care, and was the real start of the modern EMS in USA [26]. In 1976 guidelines for trauma care was published in “*Optimal Hospital Resources for Care of the Injured Patient*” by the American College of Surgeons’ Committee on Trauma [77] and the same year Orthopedic Surgeon Dr. J.K. Styner developed Advanced Trauma Life Support (ATLS) [78].

The development of the American College of Surgeons’ criteria for classifying the level of care that acute care hospitals can provide was also a starting point for the development of trauma systems in the USA [70, 79, 80].

Developing trauma systems is a complex process since each region has its own special needs, depending on the population and the demographics of the area to which the system has to be adapted [67, 80, 81]. A system for urban populations is different from a rural one and thus, in some countries, there might be a need for several systems. Another important aspect is that the injury type differs depending on the region or country. In Europe, the dominant type of injury is blunt trauma while, in the USA and South Africa, penetrating trauma is more usual [67, 73].

The guidelines for trauma care from the WHO were first published in 2004 [82] and the first WHO guidelines for trauma quality improvement programs in 2009 [83].

Over the past 40 years, the development and implementation of trauma systems has contributed to a trauma mortality reduction of 15–20%. [84–92]. Overall, during recent decades, few studies have contradicted the favorable effect of trauma system care [93, 94]. However, more than a half of the mortality reduction is due to the development of more efficient and effective EMS systems in terms of shorter prehospital time, trauma center development and designation, and shorter time to definitive care, but also in terms of the level of care that is provided in the system [89]. It has also been shown that injury severity (Injury Severity Score, ISS <15), patient age, type of injury (blunt/penetrating), presence of severe head injury, and hypotension are more important when predicting mortality than the number of patients treated by a single trauma surgeon [87]. It is crucial to understand that it takes several years for a trauma care system to mature before it can function at its best [95]. Even though mortality and morbidity reduction are important, the overall purpose of a trauma care system is to improve the functional outcome [73] for severely injured patients and to improve the quality of life after an injury. Concerning this aspect of the effectiveness of trauma systems, evidence is still lacking and it is definitely an area for future studies [68].

1.4.1 Types of trauma systems

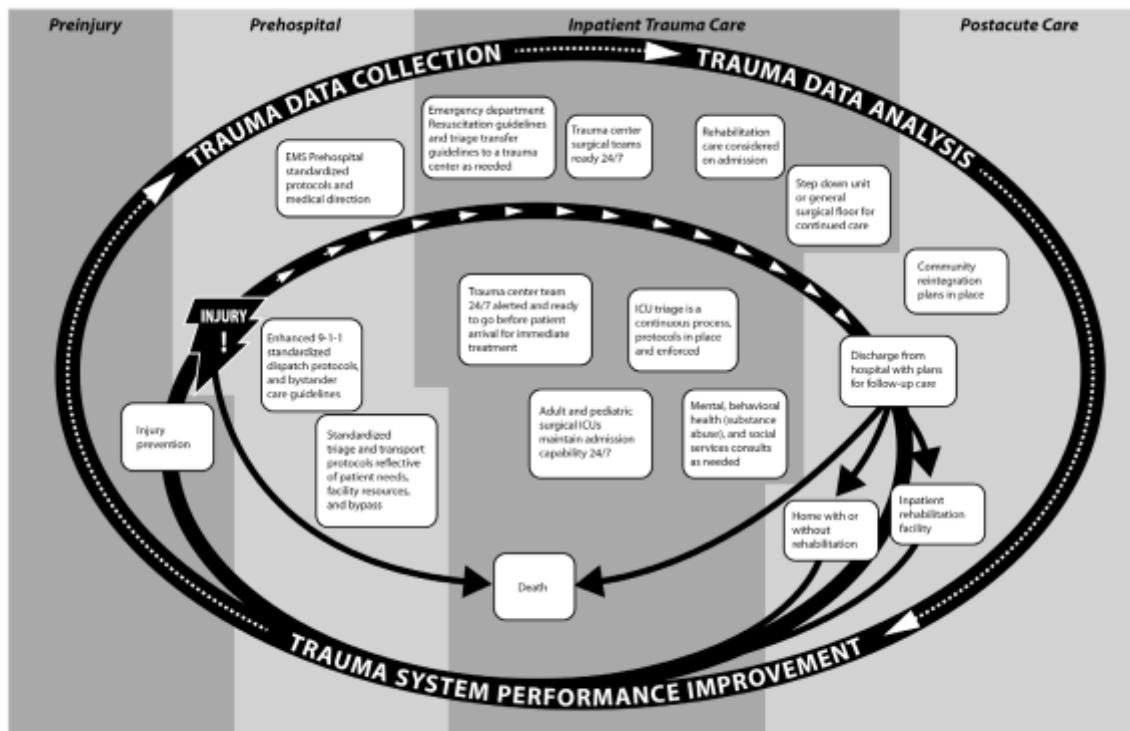
Two different types of trauma system can be outlined. In an “exclusive” system, the care is organized around a level-1 trauma center designed to attend immediately and serve the most severely injured patients [86, 91].

The “inclusive” type of system is designed to serve all injured patients and includes all levels of care in a certain region, without respect to injury severity [96]. It is about transporting patients and treating injuries at the right level of care and not referring patients with minor injuries to a major trauma center [97, 98]. In this way, the available healthcare resources can be used optimally [86]. Ideally, all hospitals with emergency departments should be prepared to care for injured patients in line with their available resources, competence, and role in the community [17 [91].

When the organization of trauma care has developed and become functional, a more integrated approach between the organization of trauma care and public health programs is called for. The public health approach handles injury as a disease and, as such, it might be prevented and/or managed [80]. The care is only a part of a chain or a part of a complex map

of activities. The start of the chain is prevention and the end is rehabilitation and re-assimilation of the patient [80].

The Figure displays an example of a complex and integrated trauma system or a trauma care chain.



Source: U.S. Department of Health and Human Services, Health Resources and Services Administration. Model Trauma System Planning and Evaluation. Rockville, MD: U.S. Department of Health and Human Services; 2006. Available at <https://www.facs.org/~media/files/quality%20programs/trauma/tsepc/pdfs/hrsa%20mtspe.ashx>. Accessed 160802. [80].

1.4.2 Trauma systems worldwide

The development of trauma systems is a process that requires cooperation between several different services, facilities, and authorities, the most important subjects and items being prehospital and in-hospital providers, insurance systems, types of injuries, and demographics in the area [67]. This is why trauma care systems differ depending on their location in the world. Generally speaking, the systems are more developed in the Western world, but still, within the European Union (EU), no standard has been stated, and basically every country in the EU has its own criteria, EMS systems, trauma organizations and systems for education, evaluation, and rehabilitation [81, 99].

1.4.3 North America and Australia

1.4.3.1 United States

The strongest efforts to create standards for trauma care were made in the US in the 1970s. At the beginning, the systems were more concentrated around the larger trauma centers, but, in the 1990s, the trend shifted towards more inclusive systems, mainly as a result of the publication “ The Model Trauma Care System Plan” [73]. In the USA, the trauma care facilities are classified and designated by the American College of Surgeons, the Committee on Trauma (ACS-COT). The facilities are divided into different levels of care (Levels I–V), depending on the updated criteria for trauma center verification, which are listed in the publication, “Resources for Optimal Care of the Injured Patient” [80]. In 2010 over 1,600 trauma centers in 40 states were classified and certified. The breakdown of the included facilities were as follows: 203 Level I, 271 Level II, 393 Level III, 765 Level IV or V, and 43 pediatric trauma centers [67]. Level I, and Level II Trauma Centers meet the same requirements. The difference is that Level I must have at least 1,200 trauma patients yearly or admit 240 with an ISS over 15 (minimum requirements) have a critical care service which is surgical, lead education and training of residents, and, finally, conduct research within the field of traumatic injuries. Outside of densely populated areas, Level II Centers might function as the leading hospital. Level III Centers might be the only medical resource in rural areas and, in those cases, the responsibility for prevention, education, and quality control also becomes their responsibility, in addition to such patients care as stabilization, treatment, and transport [80]. The role of the Level IV Center is to make the first assessment and the biggest difference from higher-level centers is that there is no surgical and/or orthopedic competence available [80].

1.4.3.2 Canada

Geographically, Canada has a mix of densely populated urban areas and large sparsely populated rural areas. Especially the central parts of the country have long transportation times. Canada has 17 medical universities and the trauma care is organized by each province. In 2008, the Interdisciplinary Trauma Network of Canada was established even though meetings and trauma improvement programs have existed since 1999. In 2005, the Trauma Association of Canada (TAC) started to designate trauma centers and their last updated guidelines are from 2011. Since the start in 2005, 25 trauma centers have been accredited: 13 Level I, one Level II, five Level III, and four Level IV or V. No national designation and verification process or national trauma care system has been established [89].

1.4.3.3 Australia

Australia has a nationwide trauma system with designated trauma centers. The country is the sixth largest in the world, but it has only about 21 million inhabitants the majority of whom are concentrated in the coastal and urban regions why a large proportion of the “outback” lacking healthcare facilities, which results in high mortality rates among trauma victims in these areas. Australia has an organization of physicians called the Royal Flying Doctor Service of Australia and it is able to reach every resident within a two-hour flight, but still, two hours is a considerable timespan in terms of prehospital trauma management. Trauma care systems and acute care facilities are organized by the individual states and designated by the regional health service or the Department of Health. There are about 16 Level I Trauma Centers for adults and about seven Level I Trauma Centers for pediatric patients. There are two types of trauma systems (urban and rural) and there are six levels of acute trauma care. The urban system has three levels (I, II, and III), corresponding approximately to the US levels of trauma center care. The rural system also has three levels: the Regional Trauma Services, which offer definitive care of non-major trauma, depending on the presence of local expertise, the Rural Trauma Services, which provides 24 -hour on-duty medical practitioners and the Remote Trauma Services, which serve the population originating from small hospitals with no on-call general practitioners [100-102].

1.4.4 Europe

1.4.4.1 United Kingdom

In the early 1940s, the Birmingham Accident Hospital was founded and was in use until the mid-1990s. In the UK, a study on major trauma care in acute care hospitals showed unfavorable outcomes, although the results were debated [99, 103, 104]. It was after the Iraq and Afghanistan wars, in which experience from the battlefield showed the importance of acute trauma care, that a trauma system was established [105]. The London trauma system was in place in 2010 and consists of four inclusive trauma care systems and four Level I Trauma Centers and, in addition, hospitals with a lower level of care. [96] [73]

1.4.4.2 Germany

The trauma system in Germany includes prevention, prehospital and in-hospital care systems, trauma center designations, rehabilitation facility units, and a structured quality control system. In 2004, the German Society for Trauma Surgery presented a suggestion for improved structure of the statewide trauma systems called the Trauma Network. The intention was to improve the quality of trauma care and cooperation between hospitals, and to

shorten the prehospital time (<30 min). The effort resulted in the “White Paper on Trauma care” in 2006. There are now about 850 acute care facilities and 57 regionalized trauma networks [67].

1.4.4.3 France

The French trauma care system does not have designated trauma centers, but there are different levels of acute care hospitals. Much of the trauma care is focused on the prehospital physician and based emergency care, i.e., the Service d’Aide Médicale Urgente (SAMU) [99]. The different types of emergency departments are the Services d’Accueil des Urgences (SAU), which have a high level of care with 24-hour availability of internal medicine, cardiology, anesthesia/intensive care, and visceral, gynecological, and orthopedic surgery. They are situated in the Hôpital de référence (Level I) or Hôpital de recours (Level II). The Pôle Spécialisé d’Accueil des Urgences is capable of the same high level of care as the SAU departments, but also has certain specialties, such as pediatric care. The Unités de Proximité d’Accueil, d’Orientation et de Traitement des Urgences are situated in smaller regional hospitals, the Hôpital de proximité (level III) with a physician 24 h/day) [67].

1.4.5 Nordic countries

The trauma systems in the Nordic countries differ somewhat from those of the rest of Europe and may not be as developed [99] [106]. The mean population density is 18 inhabitants per km² (range 2.8/km² to 125/km²) [107]; thus, a large number of the patients live in rural areas. Prehospital transport may take a considerably long time and depends on the season and whether the cases are more or less complicated [108]. The EMS system in all countries is basically three-tiered and divided into basic life support (BLS), advanced life support (ALS), and physician-manned units [107] [106]. The EMS systems in the different countries have some differences, mainly concerning the participation of EMS physicians in the prehospital care. Traditions in all countries assume that the specialization of the EMS physicians is anesthesiology and intensive care. Norway has 19 HEMS and ground-based EMS units headed by an anesthesiologist. The Royal Norwegian Air Force also contributes helicopter units in remote areas [109]. There are 37 acute care facilities that receive trauma patients and four trauma centers [110]. There is not yet a national trauma system in place in Norway, but the process is in progress [111]. In Finland, there have been five government-funded HEMS units manned by EMS physicians since 2010. Denmark has had ground units with anesthesiologists for several years and also three HEMS units, introduced in 2014 [109]. In 2007, the National Danish Board of Health recommended reducing the number of hospitals

treating acutely ill patients from 44 to 21, including 4 Level-1 Trauma Centers at the university hospitals [112].

1.4.6 Sweden

The first ambulances in Sweden were horse wagons in Stockholm during the first years of the 20th century; the first motorized ambulances were bought by the Johannes Fire Department in Stockholm and were only used for transportation [69]. Years later, in the early 1970s, a short medical course for the drivers became mandatory. During the 1980s and 1990s, EMTs and, later, nurses became the regular crew in the units and, from 2005 onward, it was stated in law that only registered nurses (RN) were allowed to administer drugs, so every ambulance crew was required to have at least one nurse. In Stockholm, in 2008, the SCC further stated that each ambulance should be manned with a specialized nurse. In the 1980s, rapid response units started to be developed in Stockholm and Gothenburg, and they were manned with nurse anesthetists or physicians [69]. In 2006, a report was released by the SCC that emphasized the need for regionalized trauma care [113] and, from 2007, all major trauma cases were to be transported to the Trauma Center at the Karolinska University Hospital in Stockholm [32], which still serves as the regional trauma center. No national trauma system has been implemented in Sweden. In the whole of Sweden, there are two ground-based EMS units headed by an anesthesiologist, but only during daytime (7 a.m. to 9 p.m.), seven days a week in Stockholm and 7 a.m. to 9 p.m. Monday–Friday in Gothenburg) and [109] nine HEMS units, but all of them are not physician-manned; some being headed by nurse anesthetists [114]. In 2014, there were seven university hospitals, 69 emergency care hospitals, and 54 emergency departments, but the three largest urban regions (Malmö/Lund, Stockholm, and Gothenburg) have some form of regionalized trauma care/trauma units [114] and the only designated trauma center corresponding to a level-1 trauma center (regarding the number of patients with ISS >15) is the one at Karolinska University Hospital in Stockholm [115].

1.5 TRAUMA REGISTRIES

Trauma registries for development and quality assessments of the trauma system have been shown to be important. A European project was developed using the Utstein Trauma Template for documenting and reporting data following major trauma [116] [117]. The template consists of a set of core data variables, which describe the patient, the process, and system characteristics. This enables researchers to compare data across regions and evaluate trauma systems.

In Sweden, a national trauma registry has been established and started collecting data in 2011 [118]. The registry covers about 50% of the traumas in Sweden [114] and uses the variables from the Utstein Trauma Template.

1.6 TRAUMA SCORES

1.6.1 Abbreviated Injury Scale

The Abbreviated Injury Scale (AIS) was first introduced in 1971 as a scoring system for determining the severity of injuries [119]. Originally, the system was intended to describe and classify the severity of injuries sustained in vehicular accidents in a systematic manner. By classifying the injury severity on a six-point scale for six anatomic regions of the body, an AIS code is derived. Through its Committee on Injury Scaling, the Association for the Advancement of Automotive Medicine (AAAM) is responsible for monitoring the use and updating of the AIS. Since its introduction, the AIS has become the basis for several other injury scales, the latest version being AIS 2005 Update 2008 [120].

1.6.2 Injury Severity Score

The ISS is an anatomical sum score developed in 1974 to assess the total severity of injury in the whole body [121]. It is based on the highest AIS severity score in each of the three most severely injured ISS body regions. The score is derived from the sum of the squares of the AIS scores ($ISS = AIS^2 + AIS^2 + AIS^2$) and it ranges between 1 and 75. The body regions are: the head and neck, the face, the chest (including the thoracic spine), the abdomen (including the pelvic contents) and the lumbar spine, and the extremities (including the pelvic girdle and external (meaning any injuries to the skin or body surface)). Trauma and the Injury Severity Score

This score is used for calculating the probability of survival, with a range of 0–100% [122]. TRISS is based on the RTS, ISS, age, type of trauma (blunt or penetrating), and coefficients derived from the multiple regression analysis from the Major Trauma Outcome Study (MTOS) database [123].

1.6.3 Glasgow Coma Scale

Since its introduction in 1974, the Glasgow Coma Scale (GCS) has been extensively used worldwide by physicians and other healthcare professionals [124, 125] and has been proven to be suitable for characterizing the changes in consciousness in TBI and trauma patients generally [124]. Limiting factors for the use of the GCS are sedation, paralysis, and intoxication [58] and a high intra-individual difference between assessors [126].

1.6.4 Revised Trauma Score

The Revised Trauma Score (RTS) is a physiological scoring system based on the following parameters, the Glasgow Coma Scale (GCS), systolic blood pressure, and the respiratory rate, to predict survival. Values range between 0 and 7.8404. Each of the parameters is coded with a number (0–4) and, depending on its value, the coded score ranges from 0 to 12 [127, 128].

1.6.5 National Advisory Committee for Aeronautics (NACA) score

The National Advisory Committee for Aeronautics (NACA) score [129, 130] consists of a scale that ranges from 0 to 7. It is used to describe injury severity. Seven signifies death by injury and zero signifies no injury. Patients who die before arrival at hospital or in the emergency department are most frequently recorded as having a NACA score of 6 or 7, and are not always captured by the trauma registries [113, 117, 131].

1.6.6 Glasgow Outcome Score

The Glasgow Outcome Score (GOS) is an instrument for assessing functional long-term outcomes in patients with traumatic brain injury. It was developed in 1975 [132] and is divided into five levels. GOS1 indicates Death and GOS5 Good Recovery. The score was revised in 1981 and three more levels were added. The revised version is called the extended GOS (eGOS) [133]. The score is intended for use at six month post injury assessment.

1.7 TRAUMA AND GENDER EQUALITY

The second paragraph of the Swedish Healthcare Law states: *"The goal of our healthcare system is to support good health and provide care on equal terms to the entire population"* [134]. Thus, it is stated in law that all healthcare in Sweden should be offered to all individuals equally and regardless of gender [135].

Gender medicine is a field of study in which disease differs between the genders in areas such as prevention, assessment, clinical symptoms, therapies, prognosis, psychological and social effects [136] [137]. It has not been a field of research of historical interest, but more attention has been paid to it during recent decades as more and more studies indicate that there are gender differences in healthcare [138-140]. The majority of studies concerning gender have been conducted within the cardiovascular field [141].

1.7.1 Cardiovascular care setting

Cardiovascular disease among females (39.3%) is slightly more common than among males (37.8%) [142]. Studies indicate that females receive less advanced care compared to males [143-146]. Female patients presenting with acute chest pain in the prehospital setting were

less likely to be treated with aspirin, nitroglycerin, and vascular access than males [143]. In a study conducted in Sweden, females presenting with chest pain had longer waiting times before treatment with such items as aspirin, coronary angiography, and admittance to a hospital ward [146]. In a study by Dodd et al., the authors concluded that females represented more than 40% of the patients with acute coronary syndrome (ACS) but represented only a quarter of the study population in clinical trials investigating the area [147]. Studies investigating care and outcomes of patients with acute myocardial infarction (AMI) showed higher in-hospital mortality in females than in males up to 70 years of age, as well as regarding six-month survival [139]. There is also evidence suggesting that females are less likely to undergo enzyme measurements, coronary angiography revascularization, cardiac monitoring, and be admitted to a coronary care unit [140].

1.7.2 Intensive care setting

Studies in the intensive care setting have indicated differences between genders in admission rates, use of mechanical ventilation, and mortality in the intensive care unit (ICU) [138, 148]. Fowler et al. showed that males were admitted to a greater extent (60.1% vs. 39.9%) to an ICU and that the difference was still evident after adjusting for age, admission diagnosis, and comorbidities [138].

1.7.3 Drugs and medical research setting

Females have been more poorly represented in medical research and clinical trials [149] [150]. Fear of affecting hormonal cycling and fertility have been suggested as an explanation for this inequality [151] [145]. Gender differences regarding drug prescription and reporting of side effects have also been studied in Sweden. Males have been prescribed more expensive and newer drugs, but females have been prescribed larger amounts of medicines (60% of all daily doses) and have been seen to report more side effects (60% vs. 40%) [145].

It is not clear whether gender differences occur in the reporting of pain and analgesia. Lord et al. noted that females reported more pain but were less likely to be treated with morphine in the prehospital setting [152]. In a study on patients with isolated injury to extremities, female patients were less likely to receive prehospital analgesia [153]. A contradictory study by Raftery et al. found that females were more likely to both report pain and receive analgesics on presenting with headache and neck or back pain in the emergency care setting [154]. No published research has investigated gender differences regarding analgesia in severely injured patients in the prehospital setting.

1.7.4 Trauma and TBI care setting

It has not been established whether gender functions as a risk factor for traumatic injuries. Males are clearly overrepresented in traumatic events in several studies and in the statistics [113, 155-159]. Brattström et al. [160] found that male gender was a risk factor for mortality at one year, but the difference appeared to be restricted only to patients >55 years old. An increase in the mortality rate among younger (<50 years old) male trauma patients was detected by Wholtmann et al. [156]. However, other studies concluded that trauma mortality seemed to be gender equal [158, 159]. The effect of gender alone regarding the outcome after traumatic events has not been demonstrated. Preclinical studies on the impact of TBI in animals showed better outcomes among females [151]. Progesterone has been hypothesized to have a neuroprotective effect [61]. However, clinical studies on humans suffering from TBI have not been able to reproduce similar results [161]. Females have the same mortality in many of the studies as males or higher [161]. The reasons are probably multifactorial and might be the result of confounders [161], or they could be partly due to gender differences in the prehospital care of TBI patients. Falk et al. compared prehospital management in patients with severe TBI admitted to neuro-intensive care and found gender differences in the prehospital assessment and treatment [162].

1.8 RATIONALE

Prehospital care is the first link in the chain of life support in trauma. The assessment triage is the first and essential part of both the prehospital care and the trauma system. It is aimed at determining the type of treatment during transport, as well as the level of trauma care. Previous studies have investigated the benefits of trauma center care for critically injured trauma patients, as well as improved outcomes in terms of mortality, morbidity, shorter time in intensive care, and the decrease in total days of hospitalization. Both overtriage and undertriage may give rise to an unfavorable impact on the trauma system. An increase in secondary transfers might lead to suboptimal care and may also result in increased mortality [163] as a result of undertriage. On the other hand, the opposite situation of overtriage might result in overcrowding of trauma centers, and thus be more cost-ineffective [164, 165]. Patients suffering from severe trauma often also suffer from a TBI, which has a major impact on the overall survival of the severely injured. The majority of the studies regarding trauma systems and trauma outcomes have been focused on countries outside of Europe [166] and outside of Scandinavia [106], but the systems vary even within Europe and all previous results may not apply to our slightly different trauma care system. The assessment triage is the basis for the way to definitive care. An evaluation of the trauma care system can therefore

be a way to evaluate the assessment of trauma patients. As mentioned before, the assessment does not just determine the transport, but also further management of the trauma patient. How to manage trauma patients in the prehospital setting has been studied in various ways, but, with only a few exceptions, how to manage TBI patients and whether gender of the patient plays a part in the management has not been an area of interest. Trauma is, to a great extent, a male disease, but with an ageing population and proportionally more women in the older age groups, the picture of the classic trauma patient is about to change. It is therefore important to examine whether there is difference in management that need to be addressed in order to provide more individualized trauma care in the prehospital setting. Some studies have pointed towards the possibility that different biological features of gender might impact trauma survival, but the literature is inconclusive.

The main objectives of trauma care are apart from survival, also to improve quality of life after the injury. During the last few decades the driving force behind the development of trauma systems has been to decrease the mortality among trauma patients, but the trend has shifted more to other outcome measures, particularly in areas with mature trauma systems where mortality has already been lowered. Evaluating whether or not the prehospital care can affect the functional outcome is an area of further development.

2 AIMS

The overall aim of this thesis was to evaluate the prehospital assessment, management, and outcome in severely injured trauma patients within a regional trauma system.

The specific aims were outlined as follows;

1. To evaluate the effect on patient flow to a regional trauma center after implementation of a prehospital trauma care protocol in a large Scandinavian city.
2. To explore gender-related differences in prehospital trauma care of severely injured trauma patients, with a special focus on triage, transportation, and interventions.
3. To explore prehospital emergency care nurses' (PECNs') documented assessments and care of patients with head trauma in a large Scandinavian city area and to study gender differences in the documented care and interventions given by the PECNs.
4. To explore the characteristics of those who received advanced prehospital airway management, including intubation, and to assess its effect on outcome, and to examine how travel time and distance to the hospital affected the management of patients suffering from TBI.

3 MATERIAL AND METHODS

3.1 ETHICAL CONSIDERATIONS

The Regional Ethical Review Board in Stockholm approved the studies included in this thesis. Reg. Nos.: 2007/1113-31, 2010/1979-32 (Paper II, III and IV), 2010/1925-31/3 (Paper I) 2013/1718-32, 2014/691-32 (Papers II, III, and IV), and 2015/1675-31/1 (Paper IV).

The study includes severely injured patients who were not able to give their consent at the time of trauma. Data collection was therefore done retrospectively and handled anonymously. Treatment and care were given according to current prehospital guidelines issued by the Stockholm County Council (SCC) and thus were not affected by the present studies. Even though specific patients may not benefit directly from the study, there might be benefits for future trauma patients in the region, as well as globally.

3.2 SETTINGS

All studies were conducted in the SCC area in Sweden, which corresponds to about one fifth of the Swedish population and consists of 26 municipalities in an area measuring 6,519 square kilometers, including an archipelago with approximately 30,000 islands [29]. The SCC is responsible for all healthcare provided in the region, including the Emergency Medical Services (EMS).

The SCC is responsible for providing EMS to a population of about 2.1 million inhabitants. The EMS is run by the company owned by the SCC and by private companies contracted by the SCC. One Emergency Medical Communications Center (EMCC) operates in the entire area.

The responses to calls are distributed among 61 ambulances (2014) and one physician-manned ambulance during the daytime. During nighttime (8 p.m.–7 p.m.) there is 38 ambulances operating the area [167], but no physician-manned ambulance. All ambulances are manned with a prehospital emergency care nurse (PECN) and an emergency medical technician (EMT), both are recertified every other year.

During 2006 and 2008, the EMS consisted of 55 ground ambulances, one ambulance helicopter (and one extra helicopter during the summer), one mobile intensive care unit (MICU), and three rapid response cars [168]. A rapid response car was called to severe accidents as a second tier providing early advanced resuscitation and assisting the regular ambulance crews. In 2008 the ambulances had a mandatory crew including a specialist nurse (prehospital, emergency medicine, anesthesiology, or intensive care). From 2008 to 2014, the

number of ambulances in the area increased to 61, but other than that the staffing and training were identical to those in 2008 [167].

The EMS personnel are required to follow prehospital medical guidelines [169], as stated by the SCC, and to document their assessment and management of the patient care given in an EMS electronic Patient Care Records System [169]

There are seven emergency hospitals, in the SCC area, but only one can be regarded as a Level-1 Trauma Center according to the American College of Surgeons' criteria, i.e., the Karolinska University Hospital in Solna. Distances to the trauma center vary between 5 km and 67 km from the other emergency hospitals.

The acute care hospitals' emergency departments (EDs) used a variety of triage systems in 2006, in which patients were categorized as triage levels 1–4/5, depending on the hospital system. In 2008 a more uniform system was implemented at all hospitals, where patients were triaged into 5 categories: red = 1, orange = 2, yellow = 3, green = 4, and blue = no triage needed. The same system was still in use in 2014.

3.3 STUDY POPULATION AND DATA COLLECTION

3.3.1 Paper I

Included in this study were adult trauma patients (>15 years of age) with an Injury Severity Score (ISS) >15, transported by ground or helicopter ambulance to any of the seven emergency hospitals in the Stockholm area during years 2006 and 2008. For the year 2013, only adult trauma patients (>15 years of age) with ISS >15 secondarily transferred to the Karolinska University Hospital Trauma Center within 24 hours from the injury were included. The secondary transfer data from 2013 were included as a “marker” for how the system had matured over the years since its introduction.

Patients with traumatic cardiac arrest and ongoing cardiopulmonary resuscitation (CPR) during transport to hospital were included, this even if they had no return of spontaneous circulation (ROSC) during transport. Trauma patients declared clinically dead on-scene, and for whom no resuscitative efforts were made, patients admitted to the hospital >24 hours post trauma, and patients suffering from asphyxia due to drowning were excluded.

Primary admissions were defined as referring to patients transported directly from the scene to a trauma center within 24 hours after the trauma; *secondary transfers* were defined as referring to patients transferred from any other hospital within 24 hours after the trauma to the trauma center.

The excluded secondary transfers were patients transferred from another county for specialist care and/or transfers >24 hours after the initial admission to the referring hospital.

We included variables according to the Utstein Template for major trauma [116]: age, gender, dominant type of injury, mechanism of injury, intention of injury, systolic blood pressure at arrival on scene, respiratory rate at arrival on scene, and according to the Glasgow Coma Scale (GCS) Score [125] at arrival on scene, cardiac arrest prehospital, type of transportation prehospital, and inter-hospital/secondary transfers. In addition, these variables were added for the purpose of the study: prehospital triage level, prehospital priority, and the Injury Severity Score (ISS) [170].

3.3.1.1 The prehospital trauma care protocol

The prehospital guidelines for trauma triage before July 1st, 2007, included only anatomical and descriptive criteria concerning the mechanism of injury and they were used to alert the receiving hospital for an incoming trauma patient. No formal protocol existed and the triage was based on the EMS crew's clinical assessment of the patient.

The triage protocol implemented in 2007 included vital parameters (systolic blood pressure <90 mmHg, the respiratory rate <10 or > 29 or Glasgow Coma Scale (GCS) Score <14) and it stated that a trauma patient should be transported to the trauma center directly even if bypassing the nearest hospital. In case of normal vital parameters, the anatomical injuries should be assessed and the trauma mechanism should be considered as part of the criteria (Figure 1). In 2011, the triage protocol was modified and the trauma mechanism was no longer a part of the assessment criteria (Figure 2).

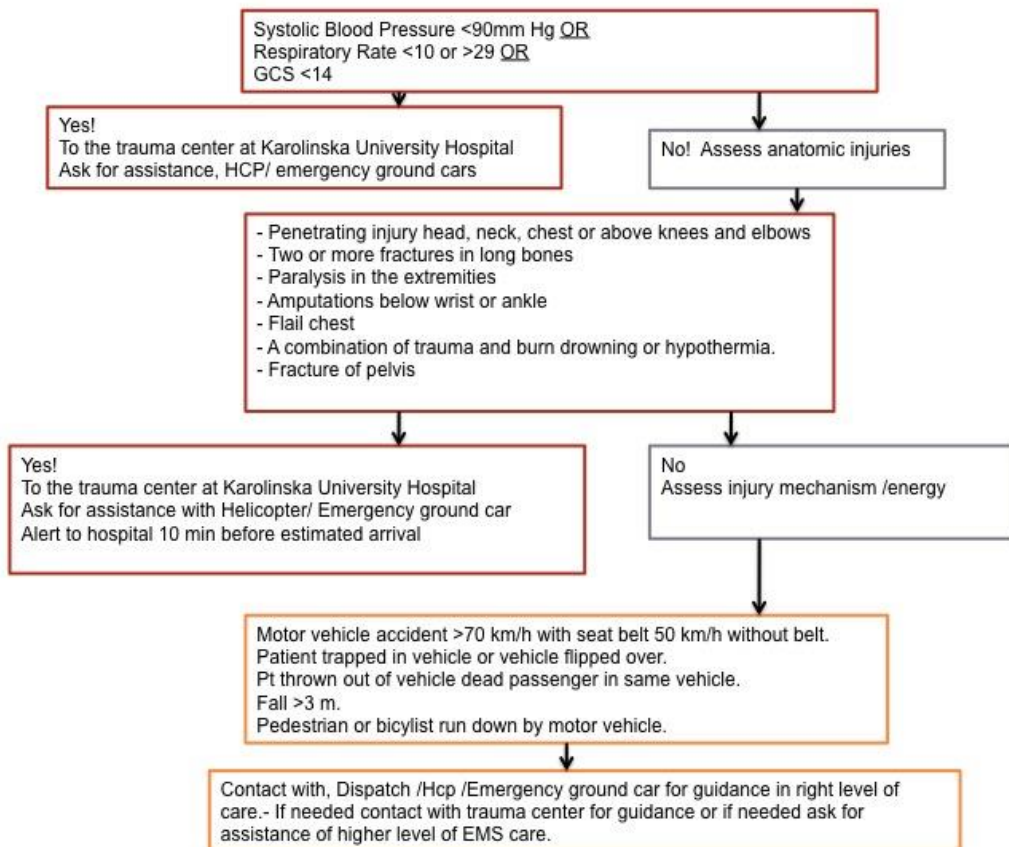


Figure 1 Trauma triage protocol 2006–2011.

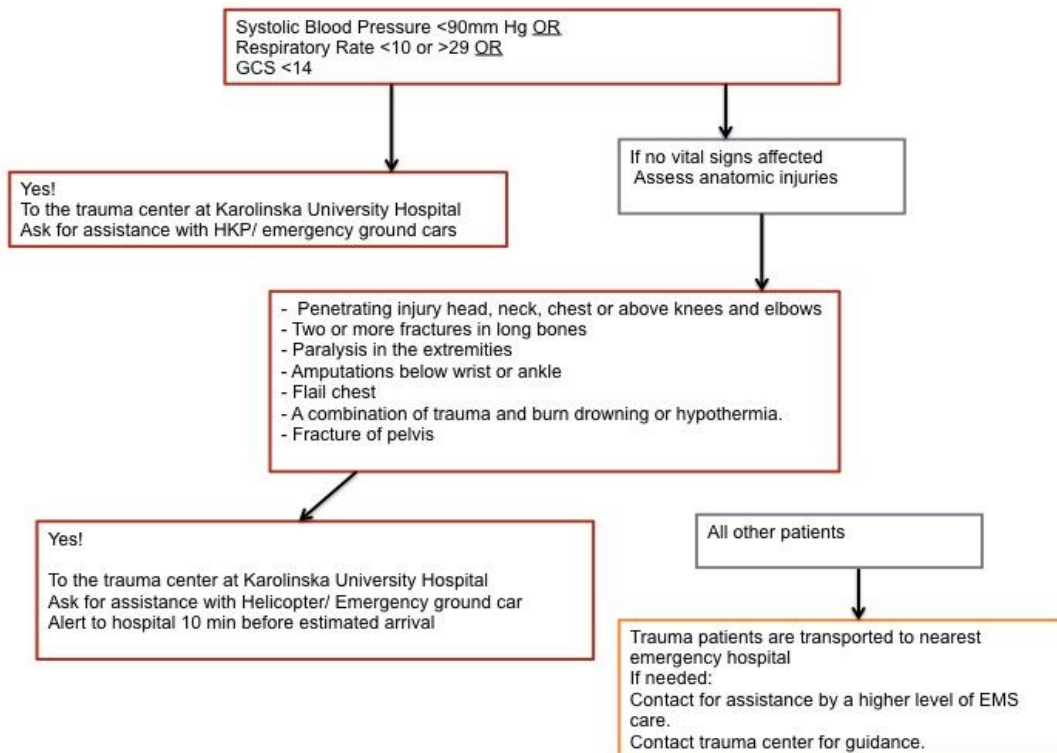


Figure 2. Trauma triage protocol from 2012 and onwards.

3.3.1.2 Data Collection

The data for 2006 and 2008 were collected from the trauma registry, “Kvalitet i Trauma Sjukvården”, KVITTRA/QUITC (version 14.0) at the Karolinska University Hospital Solna and Huddinge). The secondary transfers data for 2006, 2008, and 2013 were collected from the Trauma Registry only at the Trauma Center.

From the second largest hospital in the area, Södersjukhuset, data were collected from their trauma registry TRAUMAREG (version TraumaSys 2000–2001, version 1.1.), and in some cases completed by data from the hospital’s digital patient registration system (Pasett-DRG, version 1.61). Data from the four other emergency hospitals were collected from the digital patient records (Take Care, Melior, and Cambio Cosmic) and from emergency department records. All patients transported by ambulance or helicopter to the surgical or orthopedic sections of the emergency departments, with a traumatic injury mechanism, an ED priority level of 1 or 2 and/or admitted to a hospital ward had their records examined for injury severity. Patients with suspected head trauma and patients directly admitted to the ICU or operating room from the ED were scanned in addition. This was regardless of the ED priority. At one emergency hospital only pre-alert trauma patients were examined for eligibility since it was not possible to obtain all hospital admission records. Prehospital data were retrieved from digital ambulance records (CAK-net) used by all ambulance caregivers in SCC. Patients were identified through their Swedish social security number (unique for every person). Foreign patients were identified through a temporary number received at the admitting hospital, thus making it possible to track patients in case of a secondary transfer between hospitals. Patients included from the four emergency hospitals lacking trauma registries, the Abbreviated Injury Score (AIS, version 2005) [120] and the Injury Severity Score (ISS) [170] were calculated.

3.3.2 Paper II

Included in this study were adult and late adolescent trauma patients (>15 years of age) with an Injury Severity Score (ISS) >15, transported by ground ambulance or helicopter to any of the seven emergency hospitals in the Stockholm area during the period January 1st–December 31st, 2008. The exclusion criteria were the same as in Paper I.

The variables recorded were age, gender, dominating type of injury, injury mechanism, ICD-10 diagnosis, intention of injury, cardiac arrest prehospital, prehospital times, prehospital competence level, type of prehospital transportation, airway management, hospital length of stay (LOS), and 30-day mortality. Variables were in accordance with the Utstein Trauma Template [17]. In addition, these variables were added for this study: prehospital priority

(priority 1/other), transport to trauma center (yes/no), fluid and analgesics administered, ISS [18], Revised Trauma Score (RTS) variables [19] and 24-hour mortality.

Primary outcome measures were prehospital priority and administered analgesics. The variable *Prehospital priority* was considered to be a measure of the overall prehospital assessment in terms of both triage and transport decision. The variable *prehospital analgesics* was considered as a measure of the prehospital care from a patient perspective.

Secondary outcomes were transport to trauma center, prehospital competence level, transportation type, airway management, fluids, immobilization, 30-day mortality, 24-hr mortality, hospital LOS, on-scene time and total prehospital time. These outcomes were chosen to provide a broader view of both the system and the prehospital care.

Data Collection

Data were collected at the same manner as described in Paper I since the same cohort from the year 2008 were used for both papers.

3.3.3 Paper III

Data for this study was collected from one of three EMS providers contracted by the SCC and accounting for 40.9% of all 185,990 EMS responses in the Stockholm area during the period studied.

EMS personnel should, after a thorough assessment and according to guidelines, determine the triage level. The triage level is based on two algorithms assessed simultaneously. One of them concerns the vital signs and the other concerns the patients' main complaints, symptoms, and signs (Emergency Symptoms and Signs-ESS). A patient who is assessed as having a suspected head trauma should be triaged as ESS code number 30, according to the ESS algorithm [169]. There are four possible triage levels (red, orange, yellow, and green) and red is considered as the most urgent.

3.3.3.1 Data collection and methods

Out of a total of 71,959 ePCR-based records during the year 2012, 2843 patients (≥ 15 years old) were assessed by the PECN as having ESS code 30 and fulfilled the inclusion criteria for the study. Ninety-three of the ePCR records were excluded (ePCR error ($n = 21$), patient was not transported to a hospital ($n = 65$), intra-hospitals transports ($n = 6$) and unknown gender ($n = 1$)) resulting in 2750 included patients.

Variables were collected from the patients' ePCR records. If documented in the ePCR record the variables were considered assessed. Variables were related to the items in the guidelines for head trauma management and were categorized as follows. Four variables in the guidelines were considered "core" variables (systolic blood pressure (mmHg) blood saturation (%), pupil responsiveness and Glasgow Coma Scale (GCS) and of certain importance.

The variable *airway* was categorized into: (1) basic airway management or (2) advanced airway management. Stabilization of the neck was categorized into: (1) fixation with a backboard and (2) fixation with a cervical collar. Drugs administered were categorized into: (1) intravenous analgesics (sufentanil, ketamine, morphine, paracetamol, alphentanil), (2) intravenous sedation drugs (propofol, diazepam, midazolam), (3) intravenous fluids (Macrodex, Ringer's acetate, sodium chloride, glucose), (4) intravenous antiemetics (ondansetron, metoklopramide), (5) intravenous vasoactive drugs (fenylephrine, epinephrine) and (6) oxygen. Other variables were the NACA (National Committee of Aeronautics) scoring system [121, 129] and the Glasgow Coma Scale (GCS) [125]. For the variable priority, three priority levels were used, and level 1 indicates the most urgent.

3.3.4 Paper IV

Included were adult and late adolescent trauma patients (>15 years of age) with a TBI verified by computer tomography (ICD-10 S06.2-S06.9), treated at the neurosurgical department at the Karolinska University Hospital and transported by helicopter or ground ambulance in the Stockholm area during the period January 1st, 2008–December 31st, 2014. Patients declared dead on scene due to trauma and for whom no resuscitative measures were taken, patients admitted to the reporting hospital > 6 hours after the trauma, and patients with uncertain trauma time were excluded. In addition, we excluded patients transported from another county for specialist care and/or transfers after >24 hours to the university hospital after admission to any of the other hospitals. Variables included are in accordance with the *Utstein-style template for documenting and reporting prehospital airway management* [171] and in addition the variables; Marshalls classification [172], Rotterdam CT-score [173], Stockholm CT-score [174] Injury severity score (ISS) and New injury severity score (NISS) [170], the biomarker S100B [175] assessed at admission and at 12-48, Intensive care unit (ICU) stay in days, survival status and the Glasgow Outcome Score [176] at 12 months were added.

3.3.4.1 Data Collection

Data were collected from the Neurotrauma Register at Karolinska University Hospital in Solna. Prehospital data stemmed from electronic prehospital records (CAK-net) used by all EMS providers during all years. Efforts were made to adjust for recent infrastructure projects in the Stockholm region during the study period in order to indicate the correct paths for the ambulances. The ambulances are equipped with a global positioning satellite (GPS) system delivering a coordinate according to the SWEREF 99 (Swedish reference frame 1999) system. The SWEREF 99 has margin of error within 0.5 meters of the WGS 84 (World Geodetic System 1984), which is used by the commercially available GPS as a reference. In the electronic prehospital record the exact address of the patient pick up were also provided. In those cases the SWEREF 99 coordinates could not be obtained, Google Maps® was used to generate the WGS 84 coordinates for the entered address (used for n = 161, 35%). The preferred ambulance route from the scene of the accident to the primary hospital was chosen. The travel time without traffic was extracted from Google Maps.

3.4 STATISTICAL ANALYSES

3.4.1 Paper I

Continuous variables were presented with the median and interquartile range (IQR). For categorical variables, count (n) and percentage (%) were used. The Mann-Whitney U test was used for continuous data and Chi-square for categorical data since none of the variables were normally distributed. The statistic software IBM SPSS Statistics (version 22.0.0.0.) was used for calculations and the level of statistical significance was set to $p < 0.05$.

3.4.2 Paper II

Medians and interquartile ranges (IQRs) were calculated for continuous variables. Counts (n) and percentages (%) were used for the categorical variables. For continuous data, the Mann-Whitney U-test was used and, for categorical data, Chi-square. The data analyses followed a methodology similar to that of Gomez et al. [8]. The parameters “prehospital priority” and “prehospital care” were analyzed using univariable logistic regression and the primary outcomes, adjusted odds ratios (ORs), with 95% confidence intervals (CIs) were determined by multivariable logistic regression analysis. In both models, females were used as reference. Regression models were analyzed separately by stratification of the covariates. The Hosmer-Lemeshow statistic was used for model calibration and the c-statistic for discrimination. The IBM SPSS Statistics software (version 22.0.0.0) was used in the analyses. The significance level was set to $p < 0.05$.

3.4.3 Paper III

Descriptive statistical analyses were used for patient demographics, assessments, and care procedures and were presented as the mean and standard deviation (\pm SD). Student's t-test was used for continuous variables and X^2 was used for categorical variables concerning frequency of care and assessments between males and females. Statistical analyses were performed using the IBM SPSS Statistics Software (versions 22.0 and 23.0) and $p < 0.05$ was regarded as statistically significant.

3.4.4 Paper IV

Continuous data were presented as medians with interquartile ranges. Since age was normally distributed, it was presented with the mean and standard deviation. The Mann-Whitney U-test and Chi-square test were used for the analysis. To correlate factors with prehospital intubation ("lrm" function in R, "rms" package), a univariate regression analysis was used [177]. For outcome predictions towards GOS levels, a univariate proportional odds regression was used [175, 178]. Unimputed data were used in the two univariate models. To illustrate the pseudo-explained variance, Nagelkerke's pseudo- R^2 was used. To determine factors independently correlated with intubation and functional outcome multivariate models, utilizing Multiple Imputation (MI) ("mice"-package in R), which included all significant parameters in the univariate analyses, were performed. Significant parameters significant in univariate analyses were included in the multivariate models and the models were bias-adjusted for multiple parameters. Dependant variables were GOS or prehospital intubation. A step-up procedure was used to examine the impact of prehospital intubation on outcome in the multivariate model. To illustrate continuous vs. categorical variables, conditional density (CD) and box plots were used. The statistical program R was used, using the interface R-studio Version 0.99.902 [177] and the significance level was set to $p < 0.05$.

There were some data missing from hospital records and this was imputed in order to optimize the multivariate analyses, so as to be able to utilize all patients. Multiple Imputation ("mice" package in R) was performed, retaining seven imputed datasets, which were used to search for parameters independently correlated with prehospital intubation and functional outcomes [179, 180].

4 RESULTS

4.1 PAPER I

In 2006, 310 patients and, in 2008, 383 patients were included. In both years the majority of the injuries were caused by blunt trauma and were dominated by traffic-related injury mechanisms. No difference in age or gender distribution was detected. The median ISS was significantly lower in 2006 than in 2008 (20 and 24, respectively, $p < 0.001$). The priority of ambulance transports did not differ, nor did the number of prehospital traumatic cardiac arrests between the years.

The number of patients transported to the trauma center increased between the years from $n = 189$ patients to $n = 307$ (20.2 %), $p < 0.001$. In 2008, patients transported to the trauma center had a significantly higher ISS score than patients transported in 2006 ($p < 0.001$) (Figures 3 and 4).

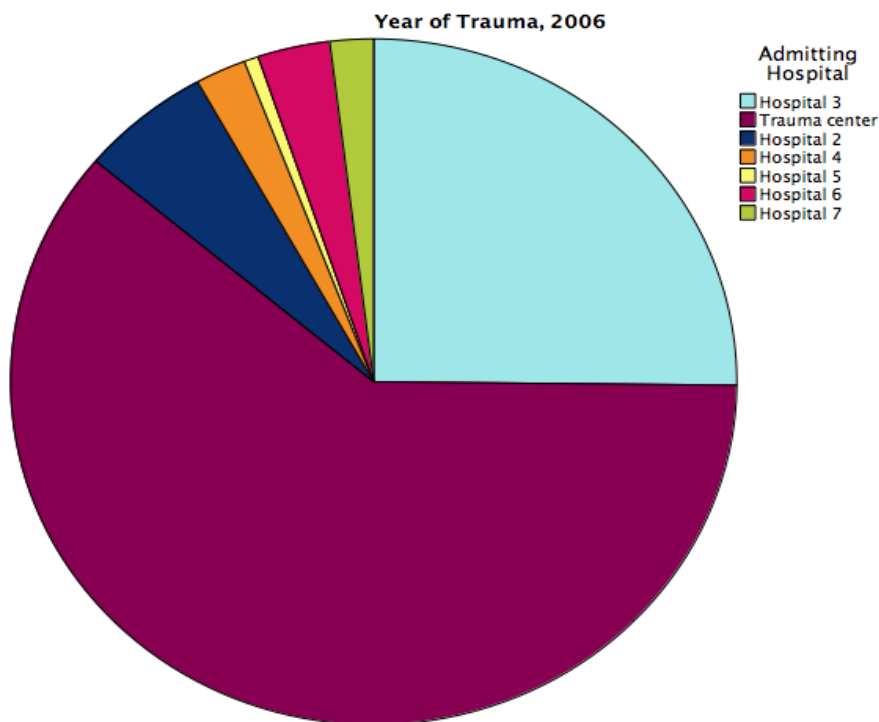


Figure 3 Distribution of patients between hospitals in 2006 pre-change.

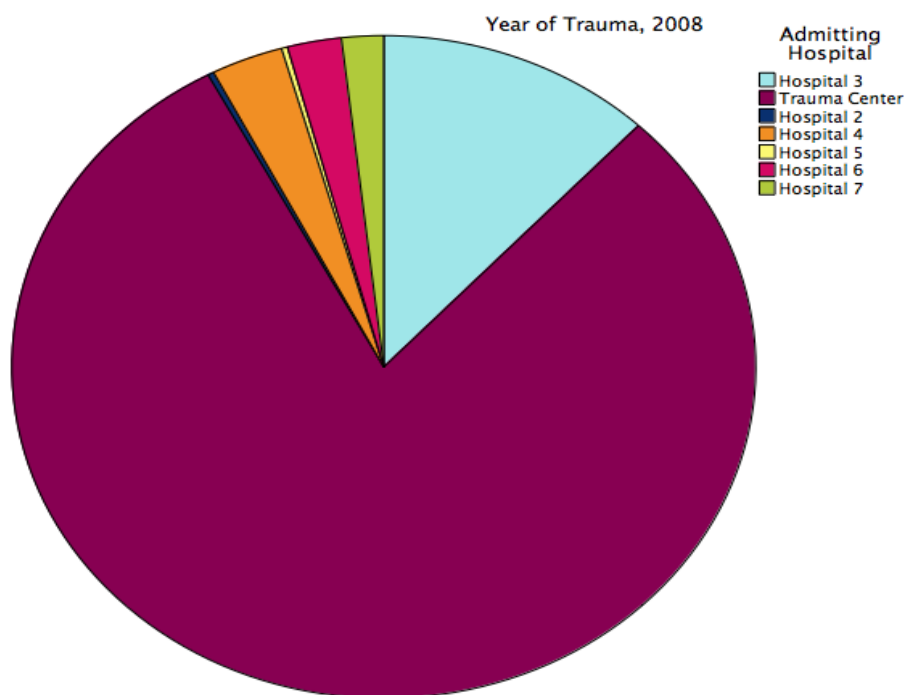


Figure 4 Distribution of patients between hospitals in 2008 post-change.

The secondary transfers decreased significantly between the years 2006 ($n = 47$) and 2008 ($n = 32$) ($p < 0.001$), but, in 2013, no further decrease was noted ($n = 35$). The characteristics of the secondarily transferred patients showed no significant differences in age or ISS between the periods studied. During all three periods, the majority of the patients were male.

4.2 PAPER II

During the study period, 383 patients, 279 males (72.8 %) and 104 females (27.2 %), with ISS >15 were included. No significant differences in age or ISS between genders were noted. Females were significantly more often represented in the group of patients with self-inflicted injuries, while the males were exposed more often to assault ($p = 0.041$). Male patients were significantly more often considered to have priority 1 ($p < 0.001$), were transported more often to the trauma center ($p = 0.016$) and were also allocated more often to the highest level of prehospital competence ($p = 0.033$).

Low-energy falls were predominant in the female group and high-energy falls ($p = 0.019$) among males. After stratifying for age and trauma mechanism, the most frequent injury mechanism in the highest age group (age ≥ 65), low energy falls, did not differ between genders. Among patients over 65 years old, low energy falls accounted for 77.8% of the female patients and 66.7 % for the males.

The univariable logistic regression analysis showed a gender difference, namely, an OR of 2.89 (95% CI, 1.6–5.1; $p < 0.001$) for male patients to be regarded as priority 1, compared to females, also after adjusting for other factors such as age, type of injury, and RTS.

The likelihood of a higher priority was relatively the same over strata, also when the analyses were stratified and adjusted for the association between the highest prehospital priority and male gender (Figure 5).

No difference between genders concerning prehospital-administered analgesics was detected. However, for the age group 15–39 years, an increased likelihood (OR, 2.11; 95% CI, 1.02–4.37; $p = 0.044$) to receive analgesics was seen. A lesser likelihood for patients with a systolic blood pressure below 90 mmHg to receive prehospital analgesics (OR, 0.4; 95% CI, 0.17–0.87; $p = 0.022$), as well as to receive analgesics if the injury mechanism was a low-energy fall (OR, 0.15; 95% CI, 0.04–0.66) was revealed in the analysis.

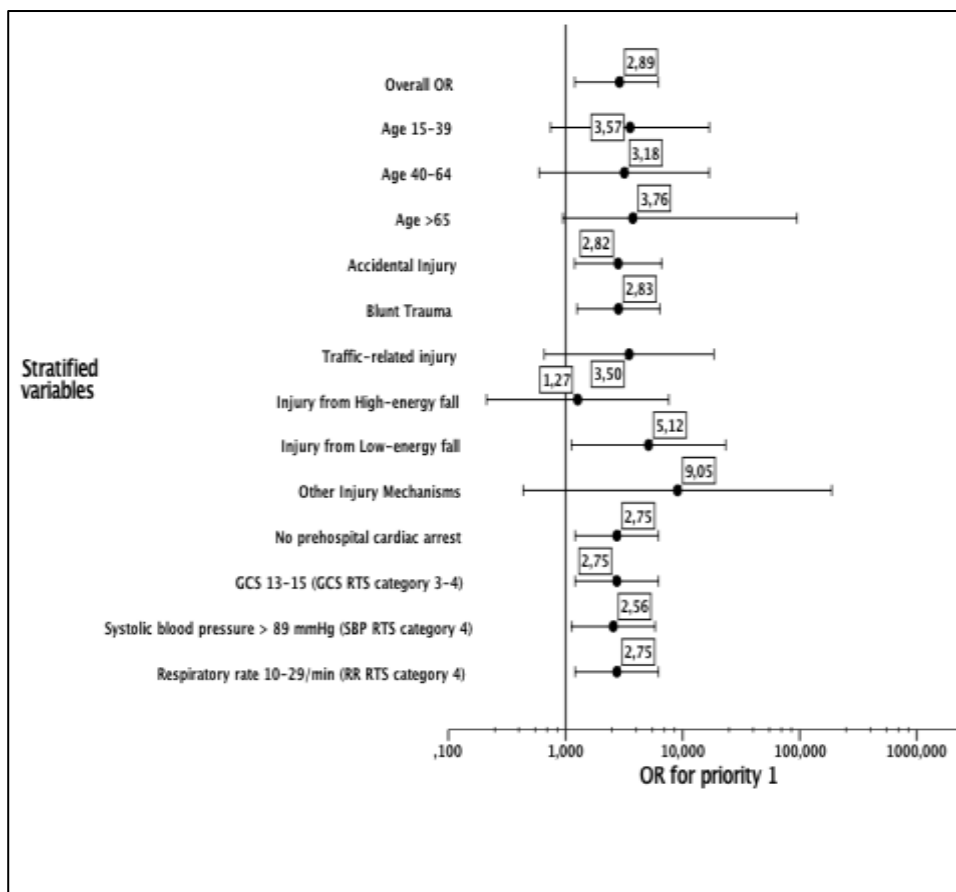


Figure 5.

4.3 PAPER III

Out of a total of 2750 eligible patients, 54.0% were males and 46.0% were female. Heart rate (96.5%) was the most frequently registered vital sign and the least frequently registered parameters were p-glucose and neurological status according to the Glasgow Coma Score. No difference between genders in injury severity, as defined by NACA score, was evident; however, there was a difference in triage levels. A subgroup analysis showed that male patients had a NACA score of 4-6 to a greater extent than female patients (59.4% vs. 43.2% $p = 0.003$) in the highest priority group (priority 1).

Some type of prehospital intervention was conducted and documented in 78.6% of the patients and 74.1% of the patients had three or more interventions within the two highest triage levels (red and orange) groups. In the lower triage groups (yellow and green), fewer than two interventions were performed in 62.8% ($p < 0.001$) of the patients. Only 25.2% of the patients were assessed regarding all four core elements in the guidelines.

Significant differences between genders regarding the assessment of core elements were seen (males 27.2 % vs. females 22.9%, $p = 0.009$), but not in the number of documented interventions (78.6% vs. 78.6%, $p = 0.272$).

Female patients were treated more often with analgesics (4.5% vs. 2.7%, $p = 0.010$) and had their vital signs documented more often than males (blood pressure, $p = 0.006$; heart rate, $p = 0.001$; temperature, $p = 0.001$; and saturation, $p = 0.004$). GCS was, however, significantly more frequently documented for males ($p = 0.003$).

4.4 PAPER IV

During the period January 1st, 2008, to December 31st, 2014, 738 TBI patients were considered for inclusion and 458 patients included. Out of these 458 patients, 178 were unconscious at the scene of the accident of whom 61 (41%) were intubated. Of the patients conscious at the scene four were intubated.

Patients in the unconscious group were more severely injured, with higher in-hospital mortality and worse long-term functional outcomes compared with the conscious patients. Among the unconscious patients, the intubated ones were almost ten years younger (38.8 vs. 48.9 years). Independent parameters explaining the variable “prehospital intubation” in the unconscious group were the mode of transportation (transported by helicopter) (pseudo- R^2 , 0.181), the amount of energy involved in the trauma (pseudo- R^2 , 0.160), time from alarm to arrival at hospital (pseudo- R^2 , 0.121), pupil responsiveness (pseudo- R^2 , 0.081), prehospital hypotension (pseudo- R^2 , 0.070) and distance from trauma to the hospital

(pseudo- R^2 , 0.068). A multiregression analysis of prehospital intubation using the significant variables in the univariate regression showed an adjusted pseudo- R^2 of 0.393. Prehospital hypoxia did not significantly correlate with prehospital intubation in a univariate analysis for the unconscious group ($p = 0.5473$). On including all 458 patients, the parameter “Unconscious” showed the greatest explained variance for prehospital intubation (pseudo- R^2 , 0.361).

An independent predictor of an unfavorable outcome in the whole cohort was prehospital hypoxia and also prehospital intubation. The distance from the trauma scene to the hospital or the total on-scene time was correlated with the long-term outcome. No differences in the intubation success rate, with reference to the care provider, were noted (EMS physician vs. nurse, $p = 0.4227$). An increasing distance from the scene to the hospital increased the rate of prehospital intubation. At >10 km, almost 50% of the patients were intubated (Figure 6). The delta-saturation did not improve significantly ($p = 0.5679$) during the prehospital transport in the intubated group (Figure 7). Sixty percent of the intubated patients ($n = 18$) transported by helicopter were intubated by the helicopter EMS rather than by the first on-scene EMS providers.

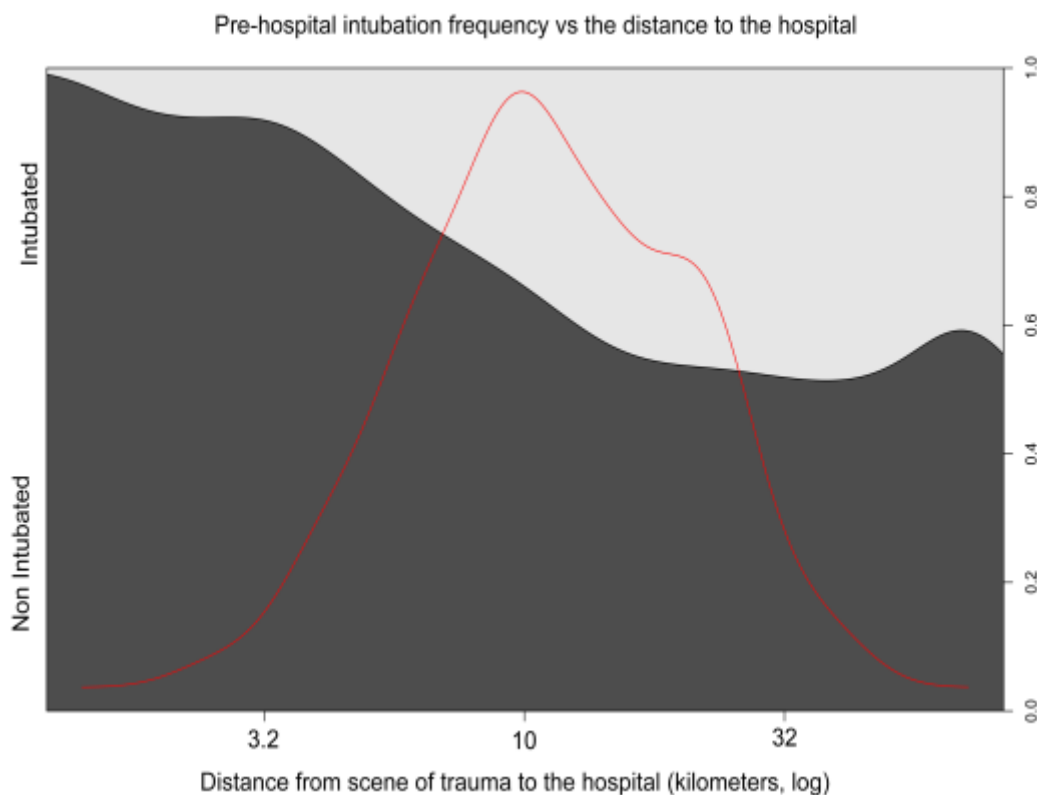


Figure 6. Distance from the trauma (x-axis, kilometers log) and the frequency of prehospital intubation (y-axis, right), bright part represents intubation (y-axis, left). The red line is a LOWESS representing the data distribution.

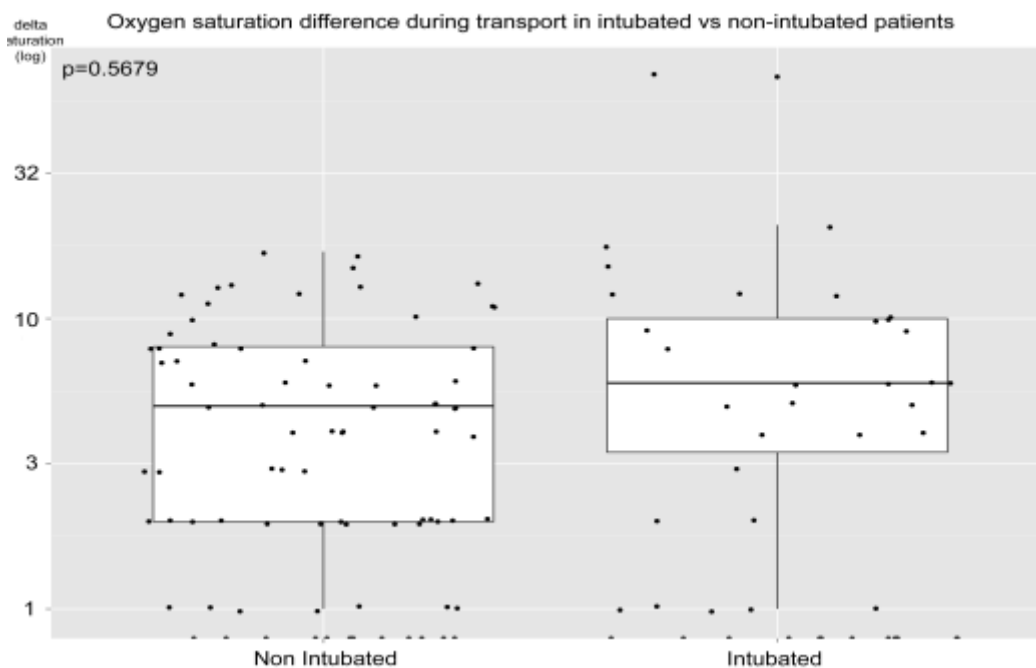


Figure 7. Difference in saturation for intubated and non-intubated patients during transportation. Mann-Whitney U-Test, $p = 0.5679$.

Independent parameters that correlated with functional outcomes in multivariate proportional odds analyses for the unconscious group were levels of S100B 12–48 hours after trauma (pseudo- R^2 , 0.302), the Stockholm CT score (pseudo- R^2 , 0.164), NISS (pseudo- R^2 , 0.099), age (pseudo- R^2 , 0.089), pupil responsiveness (pseudo- R^2 , 0.082). This model showed an adjusted pseudoexplained variance to a long-term GOS of 0.502 (this defined as a “core” model). Prehospital intubation did not correlate with outcome ($p = 0.2959$) or add any independent explained variance to the core model ($p = 0.1536$).

5 DISCUSSION

The overall objective for this thesis was to explore the assessment, management, and, to a certain extent the outcome for severely injured trauma patients in our particular region.

In Paper I, we aimed to evaluate the effect on patient flow to a regional trauma center after implementation of a prehospital trauma care protocol in a large Scandinavian city. In Paper II, we aimed to explore gender-related differences in the prehospital trauma care of severely injured trauma patients, with a special focus on triage, transportation, and interventions. In Paper III, the objective was to explore prehospital emergency care nurses' (PECNs') documented assessment and care of patients with head trauma and to study gender differences in the documented care and interventions given by the PECNs. In Paper IV, we focused on exploring characteristics of TBI patients treated according to advanced prehospital airway management, including intubation, and to assess its effect on outcome, and also to examine how travel time and distance to the hospital affected the management.

5.1 PREHOSPITAL TRAUMA FIELD TRIAGE AND ASSESSMENT IN RELATION TO TRANSPORTATION

Over the past 40 years, trauma systems and regionalized trauma care have resulted in a reduction of trauma mortality by almost 20% [84-92]. To a large extent, the reduction is a result of improvements in the EMS systems regarding such variables as shorter prehospital times, trauma center designation, and shorter time to receiving definitive care, and the level of trauma care provided [89]. These components originate in an efficient and correct trauma assessment triage, which is the basis for further care and the transport designation. It is therefore the assessment of trauma patients in the field that needs to be optimised. Undertriage might lead to a fatal outcome [163] and overtriage might result in trauma center overcrowding and unnecessary economic costs [164, 165]. Improved survival and functional outcomes for patients transported to a Level I Trauma Center, compared to those transported to a Level II Center, were reported by Cudnik et al. [181] and, in addition, they noted that intracranial injury and/or skull fractures, as well as pelvic fractures, showed more favorable outcomes when treated at a Level I Center. Demetriades et al. [182] and Garwe et al. reported similar results, i.e., a survival benefit for patients transferred to a level I facility from level III or IV facilities [183].

Other studies have, however, reported no survival benefit regarding direct transportation to trauma centers [184-187]. Haas et al. [188] have debated a limitation in terms of value since the findings were based on data from trauma registries in which no account was taken of

those who died prior to transfer. Haas et al. reported an increased mortality rate of 25% for inter-facility transferred patients, including patients who died while waiting for transfer, and concluded that a higher mortality was associated with undertriage and thus primary admission to a trauma center was beneficial. There are some studies reporting transportation of severely injured patients to non-trauma centers with proportions between 30% and 60% [189, 190].

A study in Australia evaluating a modified version of the ACS-COT prehospital trauma triage protocol in an urban setting reported that about 25% of injured patients were transported to non-trauma hospitals [191]. The trauma triage protocol they studied is similar to the protocol that has been implemented in our area, so their results are of interest to us. In our study, we did, however, focus on evaluating the ability of the new trauma system to direct severely injured trauma patients to the trauma center and not on evaluating the actual performance of the triage criteria. With almost 20% of the patients in our study still not being transported directly to the trauma center in 2008, there is a possibility that the performance of the triage protocol was not optimal at that point. This may not mean that the transport directives or the criteria were not followed or that the assessments were not made according to protocol, because this study was not designed to evaluate the criteria. We believe that the results mainly imply the difficulties and uncertainties of field triage why further research is needed. Demetriades [182] and Meisler et al. reported that early transfer to a trauma center might have survival benefits [88] and Nirula et al. concluded that there was an increased risk of mortality for secondary transfers [192]. Mortality was beyond the range of our study, but all patients in our sample were severely traumatized (ISS score >15) and one might assume that the majority of these patients would benefit from trauma center care. Our results in Paper I indicate that the implementation of the prehospital trauma care protocol may have an effect on primary transportation rates for severely injured trauma patients. We could detect a decrease in secondary transfers to the regional trauma center after one year, which still persisted seven years after the change in organization. Primarily admitted patients to the trauma center after the change were also more severely injured than patients transported to other emergency hospitals in the area in our cohort.

When focusing on other aspects of the transport decision, we found that gender might have an impact. In Paper II, we found that female trauma patients were less likely to be given the highest prehospital priority and were more often transferred secondarily to the trauma center. Chang et al.[193], reported similar findings and demonstrated a higher likelihood for males to be transported to a trauma center than females, as well as Hsia et al. [194] and Gomez et al. [195], who demonstrated a lower likelihood of females being admitted to a trauma center

even after adjusting for other factors (age, injury severity, type of prehospital provider, and mechanism of injury). Prehospital prioritization is one of the key factors in the prehospital trauma assessment and, as discussed above, it is also decisive for the timely delivery of adequate trauma care. Earlier studies on the association between gender and trauma mortality have been inconclusive [155]. Different biological features of males and females have been suggested to impact trauma survival and some have argued that estrogens are protective in terms of survival after trauma-related shock. Haider et al. reported a 14% lesser risk of dying from trauma-related shock in females in the fertile period, compared to males [196]. On comparing males with pre- and postthoronal females, the difference has not been evident. Some studies have reported male gender as a risk factor for one-year mortality, but not for 30-day mortality in elderly populations [160], while no differences in mortality between genders have been detected in other studies [197, 198]. Despite the possibility that there might be differences in mortality depending on gender, there is no conclusive evidence on which to create guidelines. Therefore, there is no reason why females should not have the same access to the highest level of care as males. One might argue the opposite, namely, that since female seem to suffer from trauma at an older age, the challenges of trauma care might be higher in this group. Geriatric patients have less tolerance to injury severity and an injury which might be overcome in a younger person, might be fatal for an older person [198]. The threshold for trauma center transportation might even be lower for an older patient and therefore the triage and assessment need to be adjusted accordingly. The existing triage criteria might not be as applicable due to physiological changes and multi pharmacy [198]. The guidelines for field triage of injured patients recommended by the National Expert Panel on Field Triage, 2011, from the Center for Disease Control and Prevention, recommend trauma center transport of patients older than 55 years [199]. However, this has not yet been implemented in our area.

In Paper III, our results pointed towards a similar result regarding gender differences when focusing on transports in relation to assessment and gender. The guidelines do consider gender in the initial prehospital management and assessment of TBI patients [200, 201]. Our results showed that all core elements in the guidelines were assessed in only about 25% of the cases and male patients were significantly more often assessed regarding all parameters than females. Male patients were also assessed to a greater extent regarding the GCS and were allocated a higher transport priority even though no gender differences regarding documented ABCD interventions were noted, although the assessed vital parameters were documented to a greater extent in the female patients. Even though no data on comorbidities could be accessed in this study, the male patients were significantly younger and therefore probably healthier. Male patients were considered to have a higher NACA score than the females in the

priority 1 group. This is interesting finding since the NACA score is a more subjective measure and may represent an unintentional bias by the EMS provider. This needs to be further explored and with other methods. An altered GCS score is one of the physiological triage criteria for trauma center transport and, as such, constitutes a possible gender bias if the assessment is carried out less often in female patients. It has been reported that the risk of developing a TBI from low-energy trauma TBI in elderly and intoxicated patients is as high as for patients exposed to high-energy trauma [202]. It has been shown that patients with an intracranial injury and/or skull fracture have a better outcome when treated at a Trauma Level I Center [181, 203]. However, in another study from our region on gender differences in prehospital TBI care, almost half of the patients were not admitted primarily to the trauma center but no effect on outcomes were reported [204].

We found that the second most frequent trauma mechanism in females was a low-energy fall (26.9%). On stratifying for age and trauma mechanism within the dominant blunt trauma group, the difference was even more evident. Gomez et al. [195] reported a similar result according to which falls from the same level constituted 41% of the trauma cases in females in their cohort, making it the most common trauma mechanism in their results regardless of age. Falk et al. also reported that falls of <3 m were the most common mechanism [204]. This might be one of the reasons why females, despite severe injury, might not be recognized at scene as potentially severely injured trauma patients, since the trauma mechanism is considered to be of low energy. Altogether, this raises the question of whether the trauma assessment triage used is gender- and/or age-neutral.

5.2 PREHOSPITAL ASSESSMENT AND MANAGEMENT OF TRAUMA IN RELATION TO GENDER

Trauma is known to be a predominantly male disease [138, 155, 197, 205, 206] and this was also the case in Paper II. Our data showed that 72.8% of the patients were males. The most common injury mechanism was traffic-related, which is consistent with other data published showing that, in Sweden, severe trauma is most frequently related to motor-vehicle crashes [207, 208], Annually, an average of 7,100 males (61%) and 4,600 females (39%) are hospitalized due to motor-related traumas [207] and in 2012, 218 males (76%) and 67 females (24%) in Sweden died in the same way [208], which shows a gender difference in mortality rates that is consistent with the worldwide rates [209].

Regarding gender differences and assessments in prehospital care, we found in Paper III that, in only about 25% of the cases, all core elements in the TBI guidelines were assessed, and male patients were significantly more often assessed regarding all parameters compared to

females. There are data pointing toward a less favourable outcome for trauma patients where a lack in documentation of basic physiological measures on scene [210] has been detected. Treatment and care decisions are made on the basis of the assessment and it is therefore crucial that it is properly performed and documented. Blood pressure, oxygen saturation, and heart rate were assessed for almost all patients, however, and, for nearly 80%, the respiratory rate was also documented. The high rate of documented and assessed respiratory data is a positive factor because the respiratory rate has previously been described as being poorly documented in clinical settings [211] and, in most scoring and triage systems, it is regarded as a key factor for identifying critical illness [212, 213]. A positive trend though the years in our data regarding respiratory rate documentation could be detected and this was noted more often in 2014 than in 2006. This is probably due to better education concerning its importance in the EMS community under the SCC and also because RR measurements, an essential part of the triage system, have been implemented in the EMS during the study period.

Some further differences between genders were also noted in Paper III. Female patients were assessed to a significantly greater extent for blood pressure, heart rate, and temperature, as well as saturation. The rationale behind this is not evident, but it might be due to the age differences.

For both genders, the assessed level of consciousness (GCS) was low and documented in less than 40% of all cases. One reason for the lack of documentation might be that, in this particular cohort, only a few patients were assessed as having symptoms of a severe TBI. Patients suffering from severe head trauma, and particularly if this is combined with other injuries, are often considered as being more critical in terms of time and would probably have been GCS-assessed to a greater extent, especially since the transport destination is dependent on the GCS score in our system. Nevertheless, observation and documentation of the patients' neurological status are important, and there are published data showing that one in ten TBI patients has a decreased GCS rating in the prehospital setting [129] and therefore re-evaluation of the GCS is very important [200, 201] . The data in Paper III clearly emphasize a need to further explore the reasons behind the low level of GCS assessments in TBI patients in the prehospital setting [169, 214].

When exploring the on-scene intervention variables in Paper II (airway management, administration of intravenous fluids, pain management, and stabilization of the neck and spine), we found no gender-associated differences, and the same was also reported by Schoeneberg et al. [155]. However, our results from Paper III on the TBI cohort did show that significantly more female patients were treated with analgesics. Other studies on the

prehospital settings have found that female patients reported more pain, but that they were less likely to be treated with morphine [152] and also that females with isolated extremity injuries were less likely to receive analgesics [215]. However, in a study by Raftery et al. [154], it was shown that the investigated patients in an ED setting who presented with headache, neck pain, or back pain were more likely to be females than males when it comes to both reporting and receiving treatment for pain, and therefore they received more analgesics.

Almost 80% of the patients in Paper III had at least one prehospital intervention. This fact points towards an individualization of trauma care which is positive finding and might be seen as an improvement since it contrast to previously published data from the same country where the authors found less need for interventions in a higher percentage of the EMS responses [216]. However one has to bear in mind that their data was not solely based on a trauma cohort. In Paper III, the assessed triage level seemed to correspond with the number of documented interventions. Patients assessed as having a higher priority received more interventions and no gender differences were detected on considering the number of interventions. During the past decade, the competency of EMS providers has increased, and the results might indicate there is a shift toward a more individually centered care.

One rather surprising finding in the head trauma population in Paper III was the low frequency of airway interventions and, in particular, intubation. This is probably related to the relatively low frequency of patients with a GCS ≤ 8 , but it might also be a result of the lack of documentation or short prehospital distances to definite care. Managing the airway to ensure a sufficient oxygen delivery is a key intervention in the prehospital care of unconscious TBI patients [217]. In Paper IV, the EMS in the Stockholm area showed compliance with the guidelines, which recommend intubation in unconscious patients and to consider intubation if the transport time is expected to be long. In our cohort, 41% of the unconscious patients were intubated and about 50% were intubated when the transport exceeded 10 km. The independent factors we found to correlate with prehospital intubation were high-energy trauma, prehospital hypotension, fixed dilated pupil(s), long on-scene time, and helicopter transportation. Among these, the strongest predictor of prehospital intubation was actually helicopter transportation. The factors behind this finding are not obvious and there are no logical reasons for the HEMS providers to be more prone to intubation than ground EMS providers. It might just be the presence of another crew on-scene that is the reason why intubation was seen more frequently in the helicopter subgroup and perhaps was not due to more severe injuries. This is probably also why the correlation between intubation and longer

on-scene times presumably is not related to injury severity, but rather is due to intubation. It might also be an effect of the high frequency of the use of the HEMS, since the HEMS was often recruited after the first EMS crew had already arrived on scene. Previously unconsciousness, respiratory insufficiency, and cardiac arrest have been described as factors influencing prehospital intubation [218] a finding similar to our results.

The importance of spending a short time on-scene has been discussed previously in the literature. Helicopter transport and/or intubation might prolong on-scene times [219, 220] and also the presence of a physician [221], but having a physician on-scene has also been reported to be associated with high-precision triage, more aggressive prehospital treatment, and rapid transport to definitive care [222]. In our results in Paper II, no gender-associated difference in the on-scene times was found. In Paper II, there was, however, a difference between gender and EMS competence (i.e., presence of a nurse anesthetist or anesthesiologist on-scene). We have not been able to find any similar previously reported findings and it is not obvious what this difference represents.

5.3 PREHOSPITAL MANAGEMENT OF TRAUMA AND TBI IN RELATION TO OUTCOME

We could not demonstrate a correlation between intubation and outcome in unconscious TBI patients. There was, however, a significant weak correlation in the combined patient cohort (both conscious and unconscious patients). It is important to explore the reasons behind the decision of the EMS to intubate in relation to the factors that independently correlate with the outcome. Regarding on-scene EMS, it is impossible to assess the extent and severity of the injury, which probably explains why the two parameters that most strongly correlate with the long-term functional outcome, the Stockholm CT score, and the 12–48-hour peak of the brain-tissue damage marker, S100B, could not be correlated with prehospital intubation.

Factors that seemed to influencing the decision to intubate on-scene followed more the field triage criteria for trauma steering, such as multi-trauma, high-energy trauma mechanisms, and the presence of prehospital hypotension. The ISS is influenced more by extracranial trauma than NISS. ISS was related to intubation and even though it is interesting result as such, it cannot be regarded as the reason behind the decision to intubate since it was calculated in retrospect and cannot be used for guidance at the scene. These parameters had little or no influence on the long-term functional outcome. Age was another aspect, increasing age being a strong predictor of an unfavourable outcome, and decreasing age was correlated with prehospital intubation (although not independently, probably because of the co-variance between younger patients and high-energy trauma). It does not seem to be the patients who

are at the highest risk for an unfavourable outcome related to the head injury that are intubated on-scene, even though they would be expected to benefit from improved monitoring of the parameters during transport.

The difference in EMS systems might also have an impact on outcome. In North America, prehospital intubation is predominantly performed by EMTs or paramedics, in contrast to Europe, where prehospital physicians are more common [171, 223]. This makes comparisons uncertain. Whether intubation should be performed under the non-optimal on-scene conditions or under better conditions in the emergency room has also been debated. An Australian RCT reported improved outcomes when RSI was performed at the scene compared to in the ED [44]. EMS provider experience was reported as a significant predictor of survival in prehospital intubated TBI patients in a meta-analysis from 2015 [224]. It has also been reported that prehospital physicians had a higher frequency of successful intubations [223], as well as less prehospital hypoxia [225]. In Paper IV, we could not find any differences in outcomes in patients intubated depending on the EMS provider level. This might be a positive result of the training given to the EMS and might also be due to the fact that the presence of prehospital physicians is relatively low in our system. The EMS/HEMS nurses thus have greater experience in intubating. The incidence of unsuccessful intubations was, however, low in our study and therefore makes comparisons difficult. Several studies have analysed the association between outcome and prehospital intubation in retrospective trauma cohorts. Some have been able to show improvement [226] and others unfavourable outcomes [227-229]. A meta-review from 2009 of prehospital intubation of TBI patients addressed these conflicting results [230].

Based on our findings in Paper IV, it is difficult to determine the benefit of prehospital intubation. It seems that the EMS assesses each patient individually and makes clinical decisions based on their clinical experience and using more subtle “hidden” skills. It also seems that prehospital intubation is more likely to be performed on patients assessed to be more severely injured and with more severe pre-trauma morbidities. This integrated, qualified, and rapid assessment is hard to quantify in this type of studies and may introduce a treatment bias. For a particular patient, the prehospital intubation may be beneficial, and sometimes even lifesaving. Our findings in Paper IV suggest that the decision to intubate or not at the scene is based on judgments that are multifactorial, which makes them hard to quantify for analysis but might be correct in a specific region or system.

An increase in unfavourable outcomes in trauma cohorts was reported by Grossmann et al. if the response time was longer than 30 minutes [231]. In our study, even though several

transports originated from peripheral islands in the Stockholm archipelago (the median distance between the scene and the hospital was 11.8 km), the median response time was just 11 minutes. Almost all of our patients had a total prehospital time of less than one hour, which is within the so-called “golden hour.” The importance of having the patients transported to hospital in less than one hour has been considered to be a cornerstone in many trauma systems, even though recent findings suggest that this time-frame may not be as important as it was once thought to be for TBI patients [232, 233].

6 CONCLUSIONS

The general conclusions drawn from this thesis were that trauma care protocol and trauma transport directives have the ability to direct severely injured trauma patients to correct level of care within the regional trauma system. There are some indications that the assessment and documentation of severely injured individuals might differ between genders. The prehospital airway management of TBI patients could not be correlated with outcomes, but with logistics in the prehospital system.

- We found an increased frequency of patients admitted primarily to the regional trauma center and a decrease in secondary transfers after implementing a trauma care protocol and a trauma transport directive. However, almost 20% of the severely injured patients were still not transported to the trauma center after implementation.
- We showed that female trauma patients were less likely to receive the highest prehospital transport priority, were less likely to be admitted primarily to the trauma center and were less often allocated the highest prehospital competence. We also found that the trauma mechanism differed between genders.
- We showed that only a quarter of all patients were assessed according to the core elements in the guidelines but also that nearly 80% of the patients underwent at least one intervention by the PECNs. The assessments documented by the PECNs were not optimal regarding all of the variables. Some gender differences were noted in the assessment and interventions in the prehospital care of patients with suspected head trauma.
- We could not show that prehospital intubation or prehospital time intervals and distances to the hospital correlated with long-term outcomes. We did find that a greater distance to the hospital increased the intubation rate.

7 FUTURE PERSPECTIVES

Mortality and morbidity reduction are essential and prioritized in all trauma care but even more important is to improve functional outcome and quality of life in severely injured patients. These aspects of the effectiveness of trauma systems need further attention, since the evidence is still lacking and should be an area for future studies. It is important to understand that a trauma care systems needs several years to mature before they can function at its best; thus, ongoing and continuous evaluation is crucial.

Our studies showed indications of gender differences in trauma care why this aspect needs to be addressed in further studies. However, using other methodologies and outcome measures might be beneficial. Further studies exploring the prehospital care of head trauma patients needs to include assessment and interventions and relate these to outcome in terms of GOS and mortality. The basis on which the assessment is made would also benefit from further exploration using other investigational methods.

Multiple confounders and possible interactions in the logistically complex prehospital setting are hard to adequately assess regarding both the benefits and risks of prehospital intubation in retrospective studies. Well-designed prospective study protocols are of importance and attempts need to be made to answer this question, especially in such a heterogeneous injury as TBI.

To further develop knowledge in the field of prehospital trauma care, large prospective multicenter studies with structured protocols are of importance for determining potential beneficial effects of advanced airway management even if logistic matters and ethical considerations might be challenging.

8 SAMMANFATTNING

Skador och olyckor tillsammans med självmord utgör de vanligaste dödsorsakerna bland yngre (< 45 år) i Sverige och svarar för cirka 4000 dödsfall årligen (15). En av de svåraste skadorna är traumatisk hjärnskada. Upp till 20 % av dessa patienter får bestående men. En effektiv traumabehandlingskedja är därför viktig för förbättrat utfall och minskade kostnader för behandling och vård. För den enskilda patienten, oavsett skada, innebär rätt vård i rätt tid på rätt plats ett mindre lidande. Eftersom majoriteten av traumapatienter är i arbetsför ålder har skadan stor påverkan på den privata ekonomin men i förlängningen även för samhället varför skadeprevention är av största vikt.

Att organisera prehospital traumavård i en storstad är en utmaning. Internationella studier har visat att regionaliserad traumasjukvård med traumacenter har gynnsam effekt för utfallet. Dock saknas motsvarande studier från Skandinavien. Den potentiella nackdelen med att transportera svårt skadade patienter till ett traumacenter skulle kunna vara ökade transporttider och att man därmed ställer ytterligare krav på den prehospitala vården, särskilt hos patienter med traumatisk hjärnskada. Den positiva effekten för patienten med direkt transport till en specialiserad traumaenhet är att den slutliga behandlingen kan påbörjas direkt vilket i internationella studier har visats leda till förbättrat utfall. Vinsten för samhället är att när patienter kommer direkt till rätt vårdnivå kan tillgängliga resurser optimeras och onödiga transporter och akutbesök reduceras. Användningen av ett standardiserat och lätt reproducerbart triageinstrument för prioritering av patienttransporter och prehospitala behandlingar har visats vara av stor betydelse och ska kunna användas på samma sätt oavsett ålder och kön. Tidigare studier inom andra medicinska områden har dock visat att det finns risk att kvinnor och män prioriteras olika. För att ett prehospitalt triageinstrument ska fylla avsedd funktion bör triagering ske på samma sätt oavsett kön.

Det övergripande syftet med denna avhandling var att utvärdera hur prehospitalt trauma omhändertagande påverkade utfallet av svårt skadade traumapatienter inom ett nytt regionalt traumasystem samt om patientens kön hade betydelse för omhändertagandet.

Studie I var en retrospektiv observationsstudie baserad på data från traumaregister, sjukhusjournaler samt ambulansjournaler i Stockholms län. 693 svårt skadade patienter som transporterats direkt till akutsjukhusen under åren 2006 och 2008 inkluderades. Vi inkluderade också svårt skadade patienter som sekundärtransporterats från de andra akutsjukhusen i länet till det regionala traumacentret på Karolinska Universitetssjukhuset (KS) i Solna för åren 2006, 2008 och 2013. Antalet som primärt lades in traumacentret ökade

med 20,2 % ($p < 0,001$) mellan åren 2006 och 2008. Dessa patienter var också svårare skadade under året 2008. Antalet sekundärtransporterade patienter var högre under år 2006 än under åren 2008 och 2013.

Studie II var en retrospektiv observationsstudie baserad på data från traumaregister, sjukhusjournaler samt ambulansjournaler i Stockholms län. 383 patienter med ISS >15 (279 män och 104 kvinnor) som transporterades till akutsjukhus i Stockholms län under 2008 inkluderades. Manliga patienter hade en 2,75 högre odds kvot för att transporteras med högsta prioritet jämfört med kvinnliga patienter även efter justering för skademekanism och vitala parametrar på skadeplats.

Studie III var en retrospektiv observationsstudie baserad på data från ambulansjournaler i Stockholms län. 2750 patienter med misstänkt skallskada inkluderades. 25,2 % av patienterna blev bedömda utifrån alla fyra kärnparametrar i riktlinjerna för skallskada och 78.6% erhöll minst en intervention i ambulansen. Män var i högre utsträckning bedömda enligt riktlinjerna och transporterades med högsta prioritet i större utsträckning än kvinnorna. Kvinnor bedömdes oftare avseende vitalparametrar och fick också oftare smärtstillande läkemedel.

Studie IV var en retrospektiv observationsstudie baserad på data från sjukhusjournaler samt ambulansjournaler i Stockholms län. Inkluderade var 451 patienter med traumatisk skallskada som vårdats på Neurokirurgiska kliniken på KS under åren 2008 - 2014. Högenergi trauma, prehospital hypotension, icke-reaktiva pupiller, transportsätt och distans till sjukhuset var oberoende parametrar relaterade till ökad intubationsfrekvens ($p < 0,001$, pseudo-R² 0,482). Prehospital intubation var inte korrelerat till utfall i gruppen med medvetlösa patienter eller relaterad till GOS. Patienter i behov av prehospital transport mer än 10 km hade en intubationsfrekvens på över 50%.

Efter att ett regionalt trauma triageinstrument och transportdirektiv i Stockholms län infördes kunde en ökning av primära och en minskning av sekundära transporter noteras. Denna skillnad var bestående efter 7 år även om ett antal patienter fortfarande transporterades till andra akutsjukhus än det regionala traumacentret. Man kunde också se att den prehospitala prioriteringen och bedömningen av svårt skadade patienter och patienter med misstänkt skallskada föreföll att skilja sig mellan könen. Prehospital intubation kunde inte relateras till vare sig sämre eller bättre utfall. Flera studier företrädesvis med prospektivt upplägg behövs för att ge mer information inom ämnesområdet.

9 ACKNOWLEDGEMENTS

I would like to express my sincere gratitude to all those who helped me with my work on this thesis.

First and foremost thank you to ALL **my dedicated colleagues** (nurses, EMTs and doctors) working days, nights, weekends and holidays in the prehospital field in Stockholm. Without you this thesis would never have been a reality.

The Karolinska Institutet, Department of Clinical Science and Education, Södersjukhuset, for taking me as a doctoral student.

My main supervisor **Sari Ponzer** who through the last years has supported me in my education to become a researcher, provided support both academic and economic, guidance and very wise comments with an incredible patience. You made the research process both challenging and inspirational and all the time did it with such grace.

A sincere thank you to my main supervisor for the first years, before moving back to Finland, and later my co-supervisor **Maaret Castren** who is the reason for this thesis in the first place, who made me apply and believed I might make it! You are an inspiration and have done so much for the academic progress of prehospital care.

My co-supervisor **Hans Morten Lossius** for insightful help and comments on my work and for always being in a good mood.

My co-supervisor **Markus Skrifvars** for prompt support whenever I had a question. Even though you are on the other side of the world you always have the time to answer within 24 hours and with spot on comments.

My mentor **Lalle Hammarstedt**, thank you for helping me reduce my research anxiety levels several times over lunch, or coffee and making me feel I might make it.

Veronica Vincente and **Veronica Lindström** thank you for being so kind and incorporating me in your work. For your support in the research group from the beginning, and for being such good colleagues “out in the field”. I look forward to the years to come!!

Eric Thelin, thank you for everything! You have helped me in numerous ways right from the start and thank you for letting me be a part of your work.

David Nelson and **Bo-Michael Bellander** for helping me. It has been a pleasure to be able to write with you. I hope I will also have the opportunity sometime in the future.

To **Katarina Bohm** for all support both with research issues along the way and with small things such as letting me use your office. But most for the way you taught me to believe in my work!

Lisa Kurland for helping me in countless ways, for including me in the emergency medicine community and for your support in my supervision of students. I really look forward to continuing to work with you.

Ralph Bolander this would not have been a dissertation without your work with the trauma directive. Thank you for all your support in so many various ways and I really look forward to continue to work alongside in the prehospital field in Stockholm.

Milka Dinevik, AISAB, for ALL your help and support in gathering data through all these years. And for the pick me up conversations we have had. I can't thank you enough!

Ellinor Berglund SÖS akuten, for helping me to get started and for all the data you helped me gather!

Hans Järnbert Petterson and **Lina Benson** for your statistical support and endless patience.

Martin Nordberg for not having the time to explore the prehospital part of trauma so I got the opportunity, and thank you for being such a good friend and colleague.

To all my colleagues in the **research group Akut!** You know who you are.

All "my" students **Karl Hanson**, **Johannes Gustavsson**, **Hanna Lövbrant**, **Nicklas Rosenqvist** and **Jens Zetterberg**, who made me evolve as a teacher as well as helping me so much in my studies.

My head of department at the department of Anesthesiology and Intensive Care at Södersjukhuset **Anne Kierkegaard** and my "bosses" **Klara Bergmark** and **Marco Schuster** for hiring me in the first place and for making it possible for me to work on my thesis through my clinical education. I know that it hasn't always been easy with making the schedule work. Thank you!

My clinical supervisor, **Ola Hansson**, who helped me manage my clinical training alongside with the research. You really made things so much easier for me, thank you.

ALL my colleagues at the department of Anesthesiology and Intensive Care at Södersjukhuset, thank you for all the support you give me every shift, and thanks for making me laugh every day at work!

Christer Svensén and **Mikael Gellerfors** thank you for all kinds of support and I hope there will be opportunities to work together in the future at our clinic too.

Nasim Farrokhnia, Head of department at Vo Akut, SÖS for the opportunity and for financial support (FoUU)

Thank you all members of the **trauma journal club** for interesting discussions.

Jeanette Örhman thanks for answering all my questions with a lot of patience for five long years.

Olof Brattström for all help with the data collection and variables.

The Trauma registrars at KS Solna and Huddinge thank you for all help in how to understand the data and for the help with data collection.

The prehospital providers in Stockholm **AISAB**, **Samariten AB** and **Falck Ambulans AB** for making it possible to collect data.

All those of you who helped me in my data collection at **Danderyds Sjukhus**, **Norrtälje Sjukhus** and **Capio St Görans Sjukhus**,

Isaac Austin for excellent linguistic help.

Åke Östman at AISAB and **Torbjörn, Ulf** and **Torkel Kanfjäll** at Samariten Ambulans AB for hiring me during the years as a prehospital nurse.

My dear friend **Emma Spetz Aurell** (and **Micke** of course) for being my cheerleaders always, always and always. Life would not be as bright without you!

The family **Funckert**, without all the nice dinners, lazy afternoons in the sun and travels I would not have coped!! I am so glad I have you as my friends.

The family **Hjort/Renström** for all the good food, for uplifting conversations and for being “stand in parents“, when I had to work or did not get home in time to pick up the kids. Next time the bubbly is on me!

My families the **Rubensons**, the **Wahlins** and the **Söllvanders**, thank you for everything through the years it is impossible to mention it all, just thanks for being there!

My wonderful kids, **Noah, Joel and Adam**. Thank you for the patience you have had when I could not show up at all the games, trainings events at school or all the nighttime stories you have missed when mummy was working late “with the computer”. I love you more than words can describe!

My beloved husband, **Hasse**, thank you for challenging me to become a prehospital nurse all those years ago. Without all your love and support and all the time you have spent at hockeyrinks, football fields and particularly all the clothes you have washed while I sat in front of my computer, spending time at the hospital, and working extra in the ambulance, this thesis would never have been written. This is your work as well as mine! I love you!

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